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PARASITIC RHIZOCTONIAS IN AMERICA

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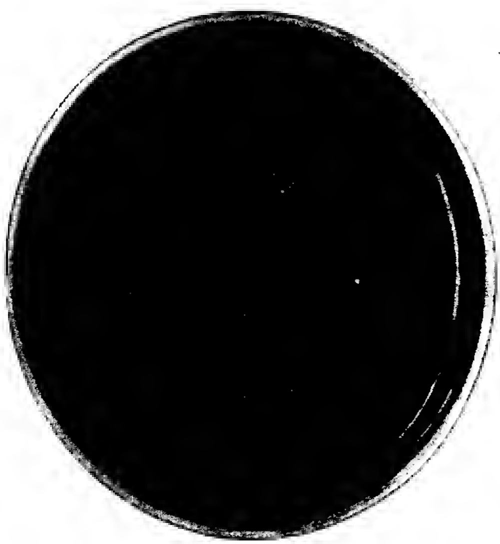

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to a fungus attacking crocus as *Thanatophytum Crocorum*. This appears, from his description and figures, to have been Rhizoctonia. A new species of Rhizoctonia was described in France by Duby[26] as *Rhizoctonia Allii* on *Allium ascalonicum*. In 1843 Levéille[65] noted a similar Rhizoctonia on *Rubia tinctorum, Solanum tuberosum, Phaseolus,* and *Tulipa,* without attempting to place it under any particular species. In 1851 the Tulasne brothers[134] classified all the forms of Rhizoctonia as a single species, *Rhizoctonia violacea,* a classification which has been adopted by a number of writers. Rhizoctonia on crocus was reported in Germany in 1858 by Kühn.[64] He also found this same fungus, which he identified as *R. Medicaginis,* on sugar beet. At the same time he described a new species of Rhizoctonia on potato, which he clearly distinguished from the above species and to which he gave the name *R. Solani.*

In the United States, Rhizoctonia was first reported by Webber[137] in 1890 on the roots of alfalfa in Nebraska. He listed the fungus as *Rhizoctonia Medicaginis* DC. The first extended account of Rhizoctonia in the United States was given by Pammel,[76] who found it causing a serious disease of beets in Iowa. Later, Atkinson[8] observed Rhizoctonia causing damping-off of cotton seedlings, and following that, of a number of other kinds of seedlings. In 1901 Duggar and Stewart[32] added a large number of hosts subject to Rhizoctonia attack. Many observations of other hosts and in new localities have since been made until at the present time Rhizoctonia has been found on one or more hosts in practically every state in this country. It has also been reported from Canada, the West Indies, South America, India, and Australia, so that it may be regarded as a truly cosmopolitan fungus.

Duggar,[*] in an article published since this manuscript was completed, brings out the fact that the violet root felt fungus, commonly known in Europe and the United States as *R. violacea,* should be referred to as *R. Crocorum* (Pers.) DC. He states that unfortunately this name has priority over the more descriptive name *R. violacea.* Under *R. Crocorum* (Pers.) DC., Duggar lists the following provisional synonymy:

Tuber parasiticum Bull. (1791)
Sclerotium Crocorum Pers. (1801)
Rhizoctonia Crocorum DC. (1815)
Rhizoctonia Medicaginis DC. (1815)
Thanatophytum Crocorum Nees (1816)
Tuber Croci Duby (1830)
Rhizoctonia Rubiæ Dcne. (1837)
Rhizoctonia Dauci Rabenh. (1859)
Rhizoctonia violacea Tul. (1862)
Rhizoctonia Asparagi Fckl. [non Fr.] (1869)
Hypochnus violaceus Eriks. (1913)

[*]Duggar, B. M.: *Rhizoctonia Crocorum* (Pers.) DC. and *R. Solani* Kühn (*Corticium vagum* B. & C.) with Notes on Other Species. Ann. Mo. Bot. Gard., 2, 403-458, 9 figs., Sept., 1915.

Under *R. Solani* Kühn (*Corticium vagum* B. & C.), the form commonly found in this country and to a less extent in Europe, and the name generally used by American authors, Duggar gives the following synonymy:

Rhizoctonia Betæ Eidam [non Kühn] (1887)
Rhizoctonia Napææ West. (1846)
Rhizoctonia Rapæ West. (1852)
Hypochnus Solani Prill. & Del. (1891)

Duggar states further that with the evidence at hand a number of species of Rhizoctonia described from Europe may be excluded from the genus, while several species are doubtful. He adds that in all probability the six species described from America, listed in Saccardo, may also be excluded, altho a more critical study of material is needed.

Many attempts have been made to connect the sterile fungus Rhizoctonia with a perfect stage. Fuckel[43] in 1869 stated that the ascomycete *Byssothesium circinans* Fkl. (*Leptosphæria circinans* Sacc.) was the perfect form. However, beyond the association of these two forms on decaying stems of *Medicago sativa,* there were no signs of their connection. The same observation was also recorded by Prunet,[90] but again with no more conclusive proof than the presence of the two forms on the same plant. Massee[66] considered Rhizoctonia as representing the vegetative condition of *Rosellinia,* because of the fact that the structure and color of the mycelium and the general habit of Rhizoctonia resembles that of the *Rosellinia quercina* Hartig and other destructive parasites belonging to that genus. He had no further evidence, however, to support this supposition.

During the summer of 1913, Cook,[20] while examining tubers affected with Rhizoctonia, found a sclerotium that contained a mass of well-developed asci bearing spores. The mycelium of the sclerotium was characteristic of Rhizoctonia and the asci appeared to arise directly from it; this point, however, could not be determined with any degree of certainty.

In 1891 Prillieux and Delacroix[89] described a basidiomycete, *Hypochnus Solani,* and altho at the time they did not associate it with Rhizoctonia, it has been accepted by a number of European writers in recent years as the perfect stage of *R. Solani.*

In 1897 Frank[41] reported *Rhizoctonia violacea* as attacking grapevines, and since a *Thelephora* was found associated with it, he proposed the name *Thelephora Rhizoctoniæ.*

In 1903 Rolfs,[93] working with the Rhizoctonia disease of potatoes in Colorado, found constantly associated with this fungus a basidiomycete which Dr. E. A. Burt identified as *Corticium vagum* B. & C., var. *Solani.* He was able to trace the connection between the two forms, and completed his evidence when he obtained cultures of Rhizoctonia from single spores of the Corticium stage.

Eriksson[38] has described a new combination, *Hypochnus violaceus* (Tul.) Eriks., which he believes is the perfect stage of *Rhizoctonia violacea* Tul. However, beyond association on different plants in the same field, he appears to have no further evidence to show that the perfect stage which he found on a number of weeds is connected with *R. violacea*, found on a number of root crops.

GENERAL CHARACTERS OF RHIZOCTONIA

The morphological characters of *Rhizoctonia Solani* Kühn vary with the age of the mycelium. The young hyphæ branch at an acute angle from the parent hypha, subsequently lying parallel to it. A constriction is shown at the point of union, and a septum is generally laid down a short distance from this point. The threads are colorless and vacuolate. With age the hyphæ lie more at a right angle with the main axis, showing less constriction. They deepen in color into a yellowish and then a rather deep brown, becoming more or less granular and empty. (Fig. 2.) Fusion of hyphæ is very common and can be observed in any young culture of the fungus. It occurs either between hyphæ of the same parent mycelium or between hyphæ from separate colonies (Fig. 2).

On many hosts a short tufted or bushy growth of the mycelium may occur with some strains. This tufted growth is likewise present

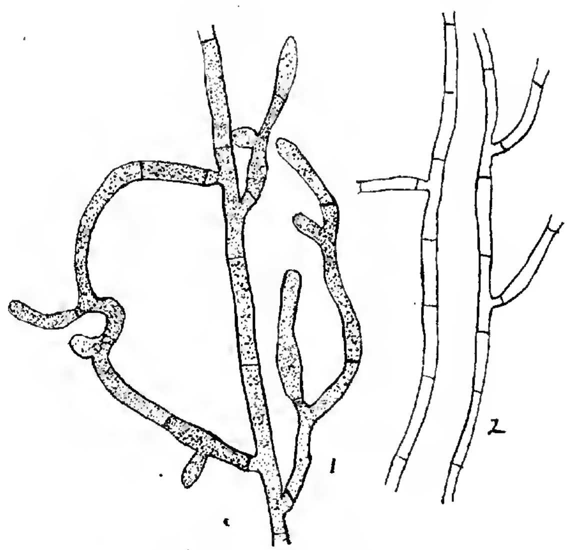

FIG. 2.—(1) YOUNG HYPHÆ OF *Rhizoctonia Solani*; (2) OLD, BROWN, AND EMPTY HYPHÆ OF *Rhizoctonia Solani*

in cultures of the strains that produce such growth on the host plants. The tufts are composed of brown hyphæ, closely septate, constricted at the septa, and often branching in an irregular manner.

Sclerotia in cultures first appear as small, soft, white masses of hyphæ. Later they become larger and turn dark and hard. Study of sclerotia at different ages shows that they are of uniform structure composed entirely of masses of irregular and barrel-shaped cells which break up into sections of one or several cells (Fig. 3). These shortened hyphal cells function as conidia and germinate readily under suitable conditions. Germination generally takes place by the protrusion of a tube thru the septum of a cell where it has broken away from an adjacent cell. In some cases the hyphæ of the germinating cells pass thru adjacent cells, which are apparently empty. Occasionally these irregular and barrel-shaped cells germinate equatorially instead of at the poles. After the germ tube has grown out some distance, it becomes narrowed near the germinating cell and a septum is laid down. The mycelium then develops in the usual manner (Fig. 4).

The formation of sclerotia in nature is rather common on many hosts. The best known examples are those formed on the potato tuber. The size and shape of the sclerotia vary considerably. On potatoes they are small, about 1 to 5 millimeters, and are generally flat. On carnation plants they may reach a diameter of 5 to 8 millimeters. When the fungus is grown on soil in pure culture, they become 5 to 6 centimeters in diameter (Fig. 5).

The sporiferous stage of *Rhizoctonia Solani* was first observed in this country by Rolfs[93] in 1903, on potato stems. It was described by Burt [94] as *Corticium vagum* B. & C., var. *Solani*.[a] In Europe this same fungus is generally known as *Hypochnus Solani* Prill. & Del.[b]

Altho the writer has observed *Rhizoctonia Solani* on seventy-five species of plants, including weeds and field, vegetable, ornamental, and floricultural crops, growing under diverse conditions and at different times of the year, for the past three seasons, it was not until the spring of 1915 that he found the Corticium stage. It was then observed in his home garden on bean, beet, radish, potato, parsnip, carrot, chard, spinach, pea, plantain, and pigweed. This stage was also found on winter vetch growing on newly plowed land, on carnation plants, and on a number of annual and perennial plants. In some cases patches of soil well protected from desiccation were covered with the ashy gray mycelium of the perfect stage.

[a]In a recent letter from Dr. Burt, he states: "I do not now believe that there is even a varietal difference between *Corticium vagum* B. & C. and that on the potatoes; hence I shall drop var. *Solani*."

[b]In his monograph on the *Thelephoraceæ*, Burt[12] limits *Hypochnus* to resupinate species with colored, echinulate spores, while under *Corticium* he includes species always resupinate, which have colorless spores and lack cystidia. According to Burt's classification, *Hypochnus Solani* Prill. & Del. becomes a synonym under *Corticium vagum* B. & C.

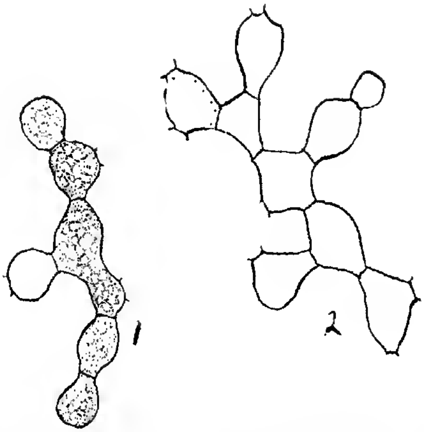

FIG. 3.—(1) YOUNG, BARREL-SHAPED CELLS WHICH COMPOSE THE SCLEROTIA OF *Rhizoctonia Solani*; (2) OLDER, EMPTY CELLS FROM THE SCLEROTIA

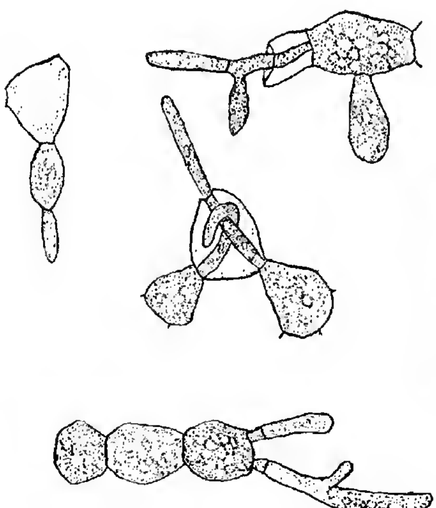

FIG. 4.—GERMINATING SCLEROTIAL CELLS OF *Rhizoctonia Solani*

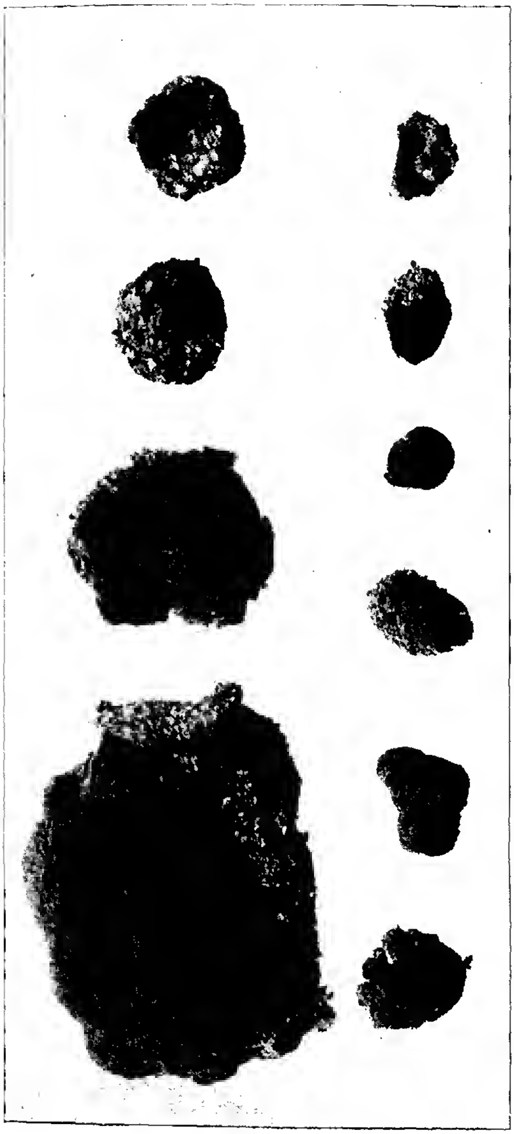

FIG. 5.—SCLEROTIA OF RHIZOCTONIA OBTAINED FROM SOIL CULTURE GROWING IN THE LABORATORY (Natural size)

The presence of the Corticium stage seems to depend on climatic conditions. A cool season with an abundance of moisture is apparently essential for its development in the field. This stage is generally found on plant tissues that are perfectly healthy; it is in no way injurious to them. Some cases have been found where it had developed on stems almost cut off by Rhizoctonia, but in no instance has the writer seen it form directly on a lesion or on injured tissue. (See Figs. 6 and 7.)

The development of the Corticium stage may be described as follows: The dark brown hyphæ of the sterile stage gather, usually at the base of the plant, and from them arises an ashy gray mycelium, which forms a fine network around the stem. The development is usually faster where a little soil, thrown up by the rains, has formed a film around the stem. The extent of this fruiting layer varies, but it may proceed several centimeters up the stem. It is so lightly attached to the plant that it may easily be rubbed off. As it becomes old, it cracks and falls off.

The outer hyphæ of the fruiting layer bear club-shaped basidia with four sterigmata and spores. Cystidia are lacking. The spores are colorless, oval to ovate, and have pointed bases. The usual spore measurement varies from 9 to 14 μ by 6 to 8 μ.

Cultures of Rhizoctonia from single spores of the Corticium stage have been obtained both by dilution methods and by the method used by Rolfs,[94] which consists in placing a stem covered with the fruiting stage over an open petri dish containing a nutrient agar, and allowing the spores to drop on the agar.

Another fungus belonging to the genus *Corticium*, *C. ochroleucum* (Noack) Burt (see footnote b, page 287), found in the United States by Stevens and Hall[117-119] on pomaceous fruits, has been carefully examined by the writer. The mycelium of this species corresponds in many respects to that of *R. Solani* and the development of the perfect stage is similar to the development of the Corticium stage of that species. It appears that these two species are very closely related, but are entirely distinct forms.

Duggar,[a] who has had an opportunity to study *R. Crocorum* (Pers.) DC. more at length, gives the following description of this species in his recent work:

"The external, general hyphæ are more or less different in form and appearance with age. The younger hyphæ are usually dilutely violaceous with a pigment which may be decolorized by the application of acidulated water. The protoplasm is dense towards the tips of branches and vacuolated farther away. The hyphæ are somewhat flexuous, branched (sometimes closely), with the branches arising at right angles to the main hypha, and with a partition wall laid down at not over 10 μ distant. With age the hyphæ become rigid, somewhat less in diameter, 4–8 μ, the branching is distant, and these branches readily break off at the first partition wall. At the point of union the diameter is uniform with the main

[a]See footnote, page 284.

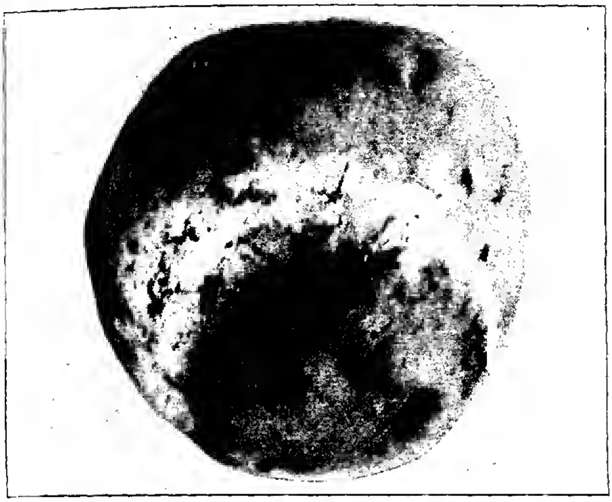

FIG. 6.—GREEN TOMATO SHOWING THE SUPERFICIAL ASHY GRAY MYCELIUM OF *Corticium vagum* B. & C. PRESENT AT THE POINT WHERE THE TOMATO TOUCHED THE SOIL

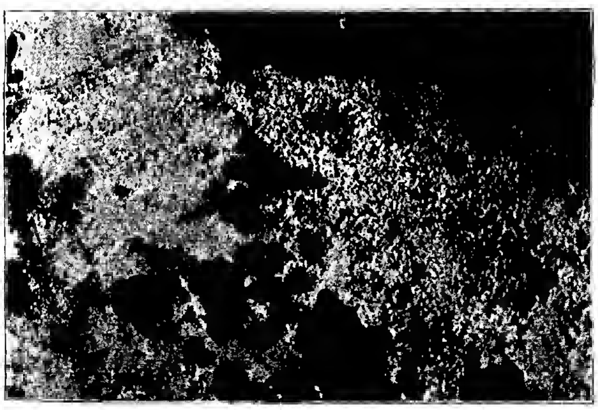

FIG. 7.—ENLARGED VIEW OF A SECTION OF FIG. 6, SHOWING THE DARK STRANDS OF HYPHÆ AND SMALL, SPHERICAL, BROWNISH SCLEROTIA OF *Rhizoctonia Solani* KÜHN WITH THE ASHY GRAY NETWORK OF MYCELIUM OF *Corticium vagum* B. & C. (5x)

hypha. The partition walls are distant, often 120–200 μ apart. The walls now possess the violet-brown pigment and in the lumen little or no protoplasm is observable.

"The internal mycelium is likewise branched, septate, often associated into loose strands, passing between the cells or traversing them. In the early stages of the disease, so far as reported, these internal hyphæ are nearly colorless...... and are generally of less diameter than those constituting the external mat.

"...... the hyphæ constituting the external mantle may be uniformly distributed, as is the case usually when the fungus attacks fleshy roots or tubers, or they may also form a number of aggregates having the appearance of loose or root-like strands."

The infection cushions are distributed over infected roots. "The external hyphæ are for the most part similar to those of the general mycelium, but there occur also branches in which the cells are short and swollen, sometimes resembling a short chain of spores..........The medullary portion of younger cushions is made up of finer, almost colorless hyphæ, and it is this type which enters—strand-like—the cortical tissues of the root, destroying particularly the cambium and younger phloem regions. In the later stages of development it will be found that the cushions seem to extend considerably into the cortex, and more of the hyphæ are colored."

"The true sclerotia are flattened or rounded bodies varying in diameter from a few millimeters to several centimeters. When mature they are of a deep violet-brown and are thickly clothed with a persistent velvety felt, externally of the same color as the root-investing hyphæ, but darkening further in. Among the surface hyphæ of the sclerotia as well as of the 'infection cushions' are found chains of enlarged cells quite distinct from the enlarged cells of *R. Solani.* The sclerotia, as noted previously, are always connected with the root felt by large hyphal strands.

"........a sclerotium consists of fairly compact tissue made up of cells often considerably branched and sometimes curiously lobed."

DISTRIBUTION OF RHIZOCTONIA IN THE UNITED STATES

In Table 1 is presented a list of those species and sub-species which have been reported as being susceptible to *R. Solani* in the United States. It is obvious that as long as investigations on this disease are continued, such a list cannot be regarded as complete or final. It may be noted that plants belonging to the families *Amaranthaceæ, Caryophyllaceæ, Cruciferæ, Leguminosæ, Solanaceæ,* and *Compositæ* are especially susceptible to this fungus. Under favorable conditions it can attack plants in these families at any stage, from seedlings or cuttings to older plants, when grown either in the field or in the greenhouse. About fifty important families of flowering plants are represented, several gymnosperms, and *Equisetum,* one of the Pteridophytes. The list includes a number of monocotyledons, which formerly were reported as being not susceptible to Rhizoctonia. Among the dicotyledons are many annuals and perennials, including herbs and woody plants, as well as most of the greenhouse and garden plants, field crops, and weeds.

R. Crocorum, as will be seen in Table 1a, has been reported so far in this country from only a few scattered states. It is probable that as investigations continue this fungus will be found in many other localities.

TABLE 1.—PLANTS REPORTED AS SUSCEPTIBLE TO *Rhizoctonia Solani* IN THE UNITED STATES

Host	State	Date	Observer	Character of Injury
Abutilon hybridum, var. *Savitzii*	Illinois	1914	Peltier	Damping-off, cuttings (greenhouse)
Acalypha Wilkesiana, var. *bicolor*	,,	1914	,,	,, ,, ,, ,,
,, ,, ,, *tricolor*	,,	1914	,,	,, ,, ,, ,,
,, ,, ,, *marginata*	,,	1914	,,	,, ,, ,, ,,
Achillea Millefolium. Milfoil	,,	1914	,,	Crown rot (greenhouse)
Actinidia polygama	New York	1910	Stewart	
Ageratum mexicanum vars.	Illinois	1914	Peltier	Damping-off, cuttings (greenhouse)
Allium sp. Onion	Colorado	1902	Rolfs	,, ,, seedlings (field)
Alyssum odoratum. Sweet alyssum	Illinois	1914	Peltier	Stem rot (greenhouse)
,, ,, ,, ,,	,,	1914	,,	Damping-off, cuttings (greenhouse)
Amaranthus albus	New York	1901	Duggar and Stewart	
,, *caudatus*	Illinois	1914	Peltier	Damping-off, seedlings (greenhouse)
,, *retroflexus*. Pigweed	New York	1901	Duggar and Stewart	
,, ,, ,,	Florida	1905	Rolfs	
,, ,, ,,	New York	1913	Burkholder*	
,, *salicifolius*	Illinois	1914	Peltier	Damping-off, seedlings (greenhouse)
,, *spinosus*	Florida	1905	Rolfs	
Ambrosia sp. Ragweed	New York	1913	Burkholder*	Stem rot (field)
,, *psilostachya*. Ragweed	Kansas	1915	Hartley and Bruner	Damping-off, seedlings (field)
Antirrhinum sp. Snapdragon	New York	1901	Duggar and Stewart	Stem rot, young plants ,,
,, *majus*. Snapdragon	Illinois	1913	Peltier	Damping-off, seedlings (greenhouse)
Apium graveolens. Celery	New York	1901	Duggar and Stewart	,, ,, ,, ,,
,, ,, ,,	Colorado	1902	Rolfs	
,, ,, ,,	Florida	1905	,,	Damping-off, seedlings
,, ,, ,,	Ohio	1907	Van Hook	Root rot (field)
,, ,, ,,	Michigan	1913	Halligan	Damping-off, seedlings
,, ,, ,,	Illinois	1913	Peltier	,, ,, ,, (greenhouse)
,, ,, ,,	Wisconsin	1914	Johnson	,, ,, ,, ,,
Aquilegia sp.	Illinois	1914	Peltier	,, ,, ,, ,,
Asclepias sp. Milkweed	Minnesota	1914	Stakman*	Plants yellowed (field)
Asparagus sprengeri	New York	1901	Duggar and Stewart	Stem rot (greenhouse)
Aucuba sp.	N. Carolina	1911	Stevens and Wilson	Damping-off, cuttings (greenhouse)
Avena sp. Side oats	Idaho	1914	Temple*	Lodging (field)
Bartonia aurea	Illinois	1914	Peltier	Damping-off, seedlings (greenhouse)

*Personal letter.

TABLE 1.—*Continued*

Host	State	Date	Observer	Character of injury
Begonia sp.	New York	1901	Duggar and Stewart	Damping-off, cuttings (greenhouse)
,, ,,	N. Carolina	1911	Stevens and Wilson	,, ,, ,, ,,
,, ,,	Illinois	1911	Anderson	,, ,, ,, ,,
Berberis ,,	N. Carolina	1911	Stevens and Wilson	,, ,, ,, ,,
Beta vulgaris. Garden beet	Wisconsin	1909	Johnson*	,, ,, seedlings (field)
,, ,, ,, ,,	Illinois	1913	Peltier	,, ,, ,, (greenhouse)
,, ,, ,, ,,	Vermont	1913	Lutman*	,, ,, (field)
Beta vulgaris. Sugar beet	Iowa	1891	Pammel	Root rot (field)
,, ,, ,, ,,	New York	1899	Duggar	,, ,, ,,
,, ,, ,, ,,	,, ,,	1901	Duggar and Stewart	,, ,, ,,
,, ,, ,, ,,	Colorado	1902	Rolfs	
,, ,, ,, ,,	California	1907	Smith	Damping-off, seedlings (field)
,, ,, ,, ,,	,,	1909	,,	,, ,, ,, ,,
,, ,, ,, ,,	—	1913	Edson	,, ,, ,, ,,
,, ,, ,, ,,	Ohio	1910	Selby	,, ,, ,, ,,
Brassica arvensis. Charlock	New York	1913	Burkholder*	
,, ,, ,,	Minnesota	1914	Stakman*	Roots slightly affected (field)
,, *oleracea.* Cabbage	New York	1895	Atkinson	Damping-off, seedlings
,, ,, ,,	Illinois	1898	Duggar and Stewart	,, ,, ,,
,, ,, ,,	New York	1901	,, ,, ,,	,, ,, ,,
,, ,, ,,	Colorado	1902	Rolfs	
,, ,, ,,	Florida	1909	Fawcett	Stem rot, seedlings
,, ,, ,,	New York	1910	Stewart	
,, ,, ,,	N. Carolina	1911	Stevens and Wilson	Damping-off, seedlings
,, ,, ,,	Pennsylvania	1913	Orton*	,, ,, ,,
,, ,, ,,	Georgia	1914	Higgins*	,, ,, ,,
,, ,, ,,	Louisiana	1914	Edgerton*	,, ,, ,,
,, ,, ,,	Colorado	1914	Longyear*	Stem and root disease (field)
,, ,, Cauliflower	New York	1901	Duggar and Stewart	Damping-off, seedlings ,,
,, ,, ,,	Louisiana	1912	Edgerton*	,, ,, ,,
,, ,, ,,	Georgia	1914	Higgins*	,, ,, ,,
,, *rapa.* Turnip	Colorado	1902	Rolfs	
,, ,, ,,	Connecticut	1914	Clinton*	Root rot (field)
Calendula Pongei. (*Dimorphotheca*)	Illinois	1914	Peltier	Damping-off, seedlings (greenhouse)

*Personal letter.

TABLE 1.—*Continued*

Host	State	Date	Observer	Character of injury
Callistephus hortensis. China aster	New York	1901	Duggar and Stewart	Stem rot (field)
,, ,, ,, ,,	Alabama	1913	Wolf*	Damping-off, seedlings (greenhouse)
,, ,, ,, ,,	Illinois	1913	Peltier	,, ,, ,, ,,
,, ,, ,, ,,	,,	1914	,,	,, ,, ,, ,,
Campanula sp.	,,	1913	,,	Stem rot (field)
,, (8 sp.)	,,	1914	,,	Damping-off, seedlings (greenhouse)
,, *persica*	Minnesota	1914	Jensen*	Roots affected (field)
Capsicum sp. Pepper	Louisiana	1914	Edgerton*	Damping-off, seedlings
,, ,, ,,	Mississippi	1914	Beal*	,, ,, ,,
Celosia Huttoni, var. *Thompsonii magnifica*	Illinois	1914	Peltier	,, ,, ,, (greenhouse)
Centaurea gymnocarpa	,,	1914	,,	Stem rot (greenhouse)
Chenopodium album. Lamb's quarters	New York	1901	Duggar and Stewart	
,, ,, ,, ,,	Illinois	1913	Peltier	Stem rot (field)
,, *leptophyllum*	Kansas	1915	Hartley and Bruner	Damping-off, seedlings (field)
Chrysanthemum hortorum	Illinois	1914	Peltier	,, ,, ,, (greenhouse)
,, ,,	,,	1914	,,	Stem rot (greenhouse)
Cineraria sp.	,,	1914	,,	Damping-off, seedlings (greenhouse)
Cirsium sp. Thistle	New York	1911	———	
Citrullus vulgaris. Watermelon	Florida	1905	Rolfs	
Citrus sp. Orange	California	1907	Smith	Root rot, seedlings
Coleus sp.	New York	1901	Duggar and Stewart	Damping-off, cuttings (greenhouse)
,, ,,	Illinois	1912	Peltier	,, ,, ,, ,,
,, ,,	,,	1913	,,	,, ,, seedlings ,,
,, ,,	,,	1914	,,	,, ,, cuttings ,,
,, ,,	,,	1914	,,	,, ,, seedlings ,,
Convolvulus arvensis. Bindweed	Minnesota	1914	Stakman*	Mycelium abundant on roots (field)
Coreopsis lanceolata	New York	1901	Duggar and Stewart	Stem rot (field)
Cratægus sp.	N. Carolina	1911	Stevens and Wilson	Damping-off, cuttings (greenhouse)
Crotalaria sp. Rattle-box	Florida	1905	Rolfs	
Cucumis melo. Muskmelon	Ohio	1910	Selby	Damping-off, seedlings (field)
,, *sativus*. Cucumber	New York	1901	Duggar and Stewart	,, ,, ,, ,,
,, ,, ,,	Ohio	1910	Selby	,, ,, ,, ,,
Cucurbita maxima. Squash	New York	1901	Duggar and Stewart	Decaying stem
,, ,, ,,	Texas	1911	Heald and Wolf	Root rot (field)

*Personal letter.

TABLE 1.—*Continued*

Host	State	Date	Observer	Character of injury
Cucurbita pepo. Pumpkin	Florida	1905	Rolfs	
Cuphea platycentra. Cigar plant	Connecticut	1904	Clinton	Root rot (greenhouse)
,, ,, ,, ,,	Illinois	1914	Peltier	Damping-off, cuttings (greenhouse)
Cyperus rotundus. Nut grass	Florida	1905	Rolfs	
Daucus carota. Carrot	New York	1901	Duggar and Stewart	Crown rot (field)
,, ,, ,,	Colorado	1902	Rolfs	
,, ,, ,,	Texas	1911	Heald and Wolf	Root rot (field)
Dianthus barbatus. Sweet william	New York	1901	Duggar and Stewart	Stem ,, ,,
,, ,, ,, ,,	Illinois	1913	Peltier	,, ,, ,,
,, ,, ,, ,,	Wisconsin	1914	Johnson	Damping-off, seedlings (greenhouse)
,, ,, ,, ,,	Missouri	1914	——	Stem rot (field)
,, *caryophyllus.* Carnation	New York	1899	Duggar	,, ,, (,, and greenhouse)
,, ,, ,,	Rhode Island	1899	Card and Adams	,, ,, ,, ,, ,,
,, ,, ,,	New York	1901	Duggar and Stewart	
,, ,, ,,	Massachusetts	1902	Stone and Smith	Stem rot (field and greenhouse)
,, ,, ,,	Connecticut	1904	Clinton	,, ,, ,, ,, ,,
,, ,, ,,	Nebraska	1906	Heald	,, ,, ,, ,, ,,
,, ,, ,,	Mississippi	1910	Thompson	,, ,, ,, ,, ,,
,, ,, ,,	New Jersey	1911	Blake and Farley	,, ,, ,, ,, ,,
,, ,, ,,	Delaware	1912	Taubenhaus*	
,, ,, ,,	Illinois	1912	Peltier	Stem rot (field and greenhouse)
,, ,, ,,	Maryland	1914	Norton*	,, ,, ,, ,, ,,
,, *chinensis*	Illinois	1914	Peltier	Damping-off, seedlings (greenhouse)
,, *deltoides*	,,	1914	,,	,, ,, ,, ,,
,, *Heddewigii*	,,	1914	,,	,, ,, ,, ,,
,, *latifolius*	,,	1914	,,	,, ,, ,, ,,
,, *plumarius*	,,	1913	,,	Stem rot (field)
,, ,,	,,	1914	,,	Damping-off, seedlings (greenhouse)
,, *sequeri*	,,	1913	,,	Stem rot (field)
Equisetum sp.	Minnesota	1914	Stakman*	
Eriobotrya japonica. Loquat	N. Carolina	1911	Stevens and Wilson	Damping-off, cuttings (greenhouse)
Erysimum pulchellum	Illinois	1914	Peltier	,, ,, seedlings ,,
Euphorbia pulcherrima. Poinsettia	,,	1912	,,	,, ,, cuttings ,,

*Personal letter.

TABLE 1.—*Continued*

Host	State	Date	Observer	Character of injury
Fagopyrum esculentum. Buckwheat	N. Carolina	1911	Stevens and Wilson	Stem rot (field)
Godetia sp.	Illinois	1914	Peltier	Damping-off, seedlings (greenhouse)
Gossypium herbaceum. Cotton	———	1855	Glover	Sore shin, young plants
,, ,, ,,	Alabama	1892	Atkinson	Damping-off, young plants (field)
,, ,, ,,	,,	1892	,,	Seedling rot ,, ,, ,,
,, ,, ,,	,,	1892	,,	Sore shin ,, ,, ,,
,, ,, ,,	,,	1899	Earle	,, ,, ,, ,, ,,
,, ,, ,,	Mississippi	1910	Hibbard	Damping-off ,, ,, ,,
,, ,, ,,	,,	1910	,,	Seedling rot ,, ,, ,,
,, ,, ,,	,,	1910	,,	Sore shin (field)
,, ,, ,,	Louisiana	1911	Edgerton*	,, ,, young plants (field)
,, ,, ,,	Texas	1911	Heald and Wolf	,, ,, ,, ,, ,,
,, ,, ,,	Alabama	1912	Wolf*	Damping-off, seedlings (greenhouse)
,, ,, ,,	Arkansas	1914	Hewitt*	Sore shin, young plants (field)
,, ,, ,,	Georgia	1914	Higgins*	Damping-off, seedlings
Gypsophila muralis	Illinois	1914	Peltier	Stem rot (field)
,, *repens*	,,	1913	,,	,, ,, ,, (greenhouse)
Helianthus annuus. Sunflower	Idaho	1914	Temple*	,, ,, mature plants (field)
,, sp. ,,	Wisconsin	1914	Johnson	Damping-off, seedlings
,, ,,	Kansas	1915	Hartley and Bruner	,, ,, ,, (field)
Heterotheca Lamarkii	Florida	1905	Rolfs	
,, *subaxillaris*	,,	1905	,,	
Hibiscus esculentus. Okra	Texas	1911	Heald and Wolf	Root rot (field)
,, sp.	N. Carolina	1911	Stevens and Wilson	Damping-off, cuttings (greenhouse)
Iberis sp. Candytuft	New York	1901	Duggar and Stewart	,, ,, ,, ,,
,, ,, ,,	Illinois	1914	Peltier	Stem rot (greenhouse)
Impatiens sp.	New York	1910	Stewart	
Ipomoea batatas. Sweet potato	Florida	1905	Rolfs	
,, ,, ,, ,,	Georgia	1914	Higgins*	Decay (field)
,, ,, ,, ,,	Delaware	1914	Taubenhaus*	
Iresine sp. (*Achyranthes*)	Illinois	1914	Peltier	Damping-off, cuttings (greenhouse)
Kochia trichophylla	,,	1914	,,	,, ,, seedlings ,,
Lactuca sativa. Lettuce	New York	1895	Atkinson	,, ,, ,,

*Personal letter.

TABLE 1.—*Continued*

Host	State	Date	Observer	Character of injury
Lactuca sativa. Lettuce....................	Massachusetts	1900	Stone and Smith	Rot
,, ,, ,, ...	New York	1901	Duggar and Stewart	Damping-off, seedlings
,, ,, ,, ...	Colorado	1902	Rolfs	
,, ,, ,, ...	Ohio	1903	Selby	Rosette (field)
,, ,, ,, ...	Florida	1905	Rolfs	,, ,,
,, ,, ,, ...	Ohio	1906	Selby	,, ,,
,, ,, ,, ...	Michigan	1909	———	
,, ,, ,, ...	New York	1910	Stewart	
,, ,, ,, ...	Oregon	1913	Bailey	Damping-off, seedlings
,, ,, ,, ...	Alabama	1912	Wolf*	,, ,, ,,
,, ,, ,, ...	N. Carolina	1912	Fulton*	Root disease (field)
,, ,, ,, ...	Pennsylvania	1912	,, et al.	Damping-off, seedlings
,, ,, ,, ...	,,	1913	Orton*	,, ,, ,,
,, ,, ,, ...	Wisconsin	1914	Johnson	,, ,, ,,
,, ,, ,, ...	Missouri	1914	———	,, ,, ,,
,, ,, ,, ...	Kentucky	1914	Gilbert*	Rot
,, ,, ,, ...	Montana	1914	Jennison*	
,, *scariola.* Prickly lettuce.............	New York	1910	Stewart	Stem rot, mature plants (field)
,, ,, ,, ,, ...	Idaho	1914	Temple*	Root rot
,, ,, ,, ,, ...	Minnesota	1914	Tolaas*	Damping-off, seedlings
Lathyrus odoratus. Sweet pea...............	Connecticut	1908	Clinton	,, ,,
,, ,, ,, ,, ...	Illinois	1912	Peltier	Stem rot
,, ,, ,, ,, ...	Delaware	1912	Taubenhaus	Damping-off, seedlings, and stem rot
,, ,, ,, ,, ...	Illinois	1913	Peltier	Yellowing of plants
,, ,, ,, ,, ...	Minnesota	1913	Jensen*	Root rot (field)
,, ,, ,, ,, ...	S. Dakota	1914	Coe*	Damping-off, seedlings (greenhouse)
Lavatera arborea variegata..................	Illinois	1913	Peltier	,, ,, ,, ,,
,, ,, ,, ...	,,	1914	,,	,, ,, ,, ,,
Lepidium sativum. Cress..................	Wisconsin	1914	Johnson	,, ,, cuttings
Ligustrum sp. Privet.......................	N. Carolina	1911	Stevens and Wilson	,, ,, seedlings (greenhouse)
Linaria Cymbalaria.........................	Illinois	1914	Peltier	,, ,, ,, ,,
,, *Maroccana*.........................	,,	1914	,,	
Linum grandiflorum rubrum.................	,,	1914	,,	Damping-off, seedlings (greenhouse)

*Personal letter.

TABLE 1.—*Continued*

Host	State	Date	Observer	Character of injury
Lobelia erinus. Single blue	Illinois	1914	Peltier	Stem rot (greenhouse)
Lychnis coeli rosa	"	1914	"	Damping-off, seedlings (greenhouse)
Lycopersicum esculentum. Tomato	Ohio	1903	Selby	Rosette (field)
" " "	Florida	1905	Rolfs	Fruit rot "
" " "	Nebraska	1907	Pool	" " "
" " "	Michigan	1910	Orton	Rosette "
" " "	Ohio	1910	"	" "
" " "	California	1911	Smith	Damping-off, seedlings
" " "	Texas	1911	Heald and Wolf	
" " "	Louisiana	1913	Edgerton	Damping-off, seedlings
" " "	D. of Columbia	1913	Wollenweber	Fruit rot (field)
" " "	Alabama	1914	Wolf*	" " "
" " "	Pennsylvania	1914	Orton*	Damping-off, seedlings
" " "	Wisconsin	1914	Johnson	" " "
" " "	Mississippi	1914	Beal*	" " "
" " "	Georgia	1914	Higgins*	" " "
Lythrum sp.	Illinois	1914	Peltier	Damping-off, seedlings (greenhouse)
Matthiola incana. Stocks	"	1914	"	" " " "
Medicago sativa. Alfalfa	Colorado	1902	Rolfs	
" " "	New York	1908	Stewart et al.	Root rot (field)
" " "	" "	1908	" "	Damping-off, seedlings (greenhouse)
" " "	Minnesota	1913	Stakman*	Root rot (field)
" " "	Illinois	1914	Peltier	Damping-off, seedlings (greenhouse)
" " "	Montana	1914	Jennison*	Root rot (field)
" " "	Louisiana	1914	Edgerton*	Crown " "
" " "	Kentucky	1914	Gilbert*	Root " "
" " "	"	1914	"	Damping-off, seedlings
Nicotiana sp. Tobacco	Connecticut	1904	Clinton	Seed-bed rot
" " "	Ohio	1904	Selby	
" " "	Connecticut	1906	Clinton	Seed-bed rot
" " "	Ohio	1906	Selby	" " "
" " "	Wisconsin	1914	Johnson	Damping-off, seedlings
" " "	Kentucky	1914	Gilbert*	Seed-bed rot
Pæonia sp. Peony	Minnesota	1913	Stakman*	Root rot (field)

*Personal letter.

TABLE 1.—*Continued*

Host	State	Date	Observer	Character of injury
Panax **sp.** Ginseng	New York	1904	Van Hook	Damping-off, seedlings (field)
Pastinaca sativa. Parsnip	Texas	1911	Heald and Wolf	Root rot (field)
Pelargonium zonale. Geranium	Wisconsin	1914	Johnson	Damping-off, cuttings (greenhouse)
Petunia sp.	Georgia	1914	Higgins*	,, ,, seedlings ,,
,, ,,	Kentucky	1914	Gilbert*	,, ,, ,, ,,
,, ,,	Illinois	1914	Peltier	,, ,, cuttings ,,
Phaseolus vulgaris. Bean	New York	1895	Atkinson	,, ,, seedlings ,,
,, ,, ,,	,, ,,	1901	Duggar and Stewart	Stem rot (field)
,, ,, ,,	,, ,,	1901	,, ,, ,,	Damping-off, seedlings (greenhouse)
,, ,, ,,	Colorado	1902	Rolfs	
,, ,, ,,	Missouri	1904	Hedgcock	Stem rot (field)
,, ,, ,,	,,	1904	,,	Pod infection (field)
,, ,, ,,	Florida	1905	Rolfs	
,, ,, ,,	Louisiana	1908	Fulton	Damping-off, seedlings (field)
,, ,, ,,	,,	1908	,,	Dry stem rot (field)
,, ,, ,,	,,	1908	,,	Seed-pod infection (field)
,, ,, ,,	New York	1910	Barrus	Damping-off, seedlings (field)
,, ,, ,,	,, ,,	1910	,,	Cankers on stem (field)
,, ,, ,,	,, ,,	1910	,,	Seed-pod infection ,,
,, ,, ,,	Ohio	1910	Selby	Root rot (field)
,, ,, ,,	Texas	1911	Heald and Wolf	,, ,, ,,
,, ,, ,,	Pennsylvania	1912	Orton*	,, ,, ,,
,, ,, ,,	Mississippi	1913	Beal*	Damping-off, seedlings (field)
,, ,, ,,	Georgia	1914	Higgins*	(Field)
,, ,, ,,	Louisiana	1914	Edgerton*	Damping-off (field)
,, ,, ,,	Maryland	1914	Norton*	Stem rot (field)
,, ,, ,,	,,	1914	,,	Pod spot ,,
,, ,, ,,	,,	1914	,,	Stem rot ,,
Phlox sp.	New York	1901	Duggar and Stewart	,, ,, mature plants (field)
Physalis Francheti. Chinese lantern plant	Minnesota	1913	Tolaas*	Root rot (field)
Phytolacca decandra. Pokeweed	Florida	1905	Rolfs	
Picea sp.	Ohio	1914	Selby*	Damping-off, seedlings
Pinus ponderosa	Kansas	1915	Hartley and Bruner	,, ,, ,, (field)
,, sp.	Nebraska and Kansas	1910	Hartley	,, ,, ,, ,,

*Personal letter.

TABLE 1.—*Continued*

Host	State	Date	Observer	Character of injury
Pinus Strobus	New York	1901	Duggar and Stewart	Damping-off, seedlings (field)
,, ,,	Connecticut	1912	Clinton	,, ,, ,, ,,
,, ,,	Maine	1914	Morse*	,, ,, ,, ,,
Piqueria trinervia (*Stevia*)	Illinois	1914	Peltier	,, ,, cuttings (greenhouse)
Pisum sativum. Pea	Colorado	1902	Paddock	Root rot
,, ,, ,,	Florida	1905	Rolfs	
,, ,, ,,	Wisconsin	1912	Johnson*	Damping-off, seedlings
,, ,, ,,	Minnesota	1913	Stakman*	Root rot (field)
Plantago sp. Plantain	New York	1913	Burkholder*	
,, *aristata.* ,,	Illinois	1914	Peltier	Crown rot (greenhouse)
Platycodon sp.	Connecticut	1904	Clinton	Stem rot, mature plants (field)
Portulaca sp. Purslane	Florida	1905	Rolfs	
,, *oleracea.* ,,	Illinois	1914	Peltier	Damping-off, seedlings (greenhouse)
Potentilla sp. Five-finger	Minnesota	1914	Stakman*	On roots (field)
,, ,, ,,	Illinois	1914	Peltier	Crown rot (greenhouse)
Primula malacoides	,,	1914	,,	Damping-off, seedlings (greenhouse)
,, *obconica grandiflora*	,,	1914	,,	,, ,, ,, ,,
Prunus sp. Cherry	New York	1901	Duggar and Stewart	On roots of dead trees (field)
,, ,, Laurel cherry	N. Carolina	1911	Stevens and Wilson	Damping-off, cuttings (greenhouse)
Punica granatum. Pomegranate	,, ,,	1911	,, ,, ,,	,, ,, ,, ,,
Pyrethrum sp.	New York	1901	Duggar and Stewart	Stem rot, mature plants (field)
Radicula armoracia. Horse-radish	,, ,,	1903	Burkholder*	
Raphanus sativus. Radish	,, ,,	1895	Atkinson	Damping-off, seedlings (greenhouse)
,, ,, ,,	,, ,,	1901	Duggar and Stewart	,, ,, ,,
,, ,, ,,	,, ,,	1901	,, ,, ,,	Crown rot, mature plants (field)
,, ,, ,,	Connecticut	1904	Clinton	Damping-off, seedlings ,,
,, ,, ,,	,,	1904	,,	Root rot, mature plants ,,
,, ,, ,,	New York	1910	Stewart	Damping-off, seedlings ,,
,, ,, ,,	Illinois	1914	Peltier	Crown rot (field)
,, ,, ,,	Wisconsin	1914	Johnson	Root rot
,, ,, ,,	Kentucky	1914	Gilbert*	Damping-off, seedlings (field)
,, ,, ,,	Missouri	1914	——	,, ,, ,, ,,
Reseda odorata. Mignonette	Connecticut	1904	Clinton	Stem rot, mature plants ,,

*Personal letter.

TABLE 1.—*Continued*

Host	State	Date	Observer	Character of injury
Rheum rhaponticum. Rhubarb	New York	1901	Duggar and Stewart	Crown rot (field)
'' '' ''	Connecticut	1904	Clinton	Stem rot ''
Richardia scabra	Florida	1905	Rolfs	
Ricinus sp. Castor bean	Kansas	1914	Melchers*	Damping-off, seedlings (field)
Rubus sp. Raspberry	New York	1901	Duggar and Stewart	
'' '' ''	Colorado	1902	Paddock	Root rot (field)
'' '' Blackberry	''	1902	''	Root disease (field)
Rumex sp. Dock	New York	1913	Burkholder*	
'' *acetosella.* Sorrel	Illinois	1914	Peltier	Crown rot (greenhouse)
Saccharum officinarum. Sugar cane	Louisiana	1912	Edgerton*	
Salvia officinalis. Mammoth sage	New York	1901	Duggar and Stewart	Damping-off, cuttings (greenhouse)
'' sp.	Ohio	1910	Selby*	'' '' seedlings ''
'' *splendens* vars	Illinois	1912	Peltier	'' '' cuttings ''
'' '' ''	''	1913	''	'' '' seedlings ''
Santolina chamæcyparissus	''	1914	''	Stem rot (greenhouse)
'' ''	''	1914	''	Damping-off, cuttings (greenhouse)
Schizanthus sp.	''	1914	''	'' '' seedlings ''
Sedum anglicum	''	1913	''	Stem rot (field)
'' *spectabile*	''	1914	''	Damping-off, cuttings (greenhouse)
Seradella sp.	Wisconsin	1914	Johnson*	'' '' seedlings
Setaria glauca. Foxtail grass	Illinois	1914	Peltier	On roots (greenhouse)
Silene Schafta	''	1914	''	Damping-off, seedlings (greenhouse)
Solanum melongena. Eggplant	New York	1895	Atkinson	'' '' '' ''
'' '' ''	Florida	1905	Rolfs	
'' '' ''	Texas	1911	Heald and Wolf	Root rot (field)
'' '' ''	Illinois	1912	Peltier	Fruit '' ''
'' '' ''	Mississippi	1912	Beal*	Damping-off, seedlings
'' '' ''	Illinois	1913	Peltier	'' '' '' (greenhouse)
'' '' ''	Alabama	1914	Wolf	'' '' ''
'' '' ''	''	1914	''	Fruit rot (field)
'' '' ''	Louisiana	1914	Edgerton*	Damping-off, seedlings
'' '' ''	Wisconsin	1914	Johnson	'' '' ''
'' *tuberosum.* Potato	Iowa	1890	Duggar and Stewart	On stem and tubers (field)
'' '' ''	''	1901	'' '' ''	'' '' '' '' ''

*Personal letter.

TABLE 1.—*Continued*

Host	State	Date	Observer	Character of injury
Solanum tuberosum. Potato	New York	1901	Duggar and Stewart	On stems and tubers (field)
,, ,, ,,	Alabama	1901	,, ,, ,,	,, ,, ,, ,, ,,
,, ,, ,,	Colorado	1901	,, ,, ,,	,, ,, ,, ,, ,,
,, ,, ,,	Ohio	1901	,, ,, ,,	,, ,, ,, ,, ,,
,, ,, ,,	Pennsylvania	1901	,, ,, ,,	,, ,, ,, ,, ,,
,, ,, ,,	Ohio	1902	Selby	Rosette (field)
,, ,, ,,	Colorado	1902	Rolfs	Stem rot ,,
,, ,, ,,	Minnesota	——	,,	
,, ,, ,,	Florida	——	,,	
,, ,, ,,	Oklahoma	——	,,	
,, ,, ,,	Texas	——	,,	
,, ,, ,,	California	——	,,	
,, ,, ,,	Washington	——	,,	
,, ,, ,,	Colorado	1903	,,	Stem rot (field)
,, ,, ,,	Connecticut	1904	Clinton	Rosette ,,
,, ,, ,,	Florida	1904	Hume	Blight ,,
,, ,, ,,	,,	1905	Rolfs	Stem rot ,,
,, ,, ,,	New York	1910	Stewart	
,, ,, ,,	California	1911	Smith	Little potato (field)
,, ,, ,,	Texas	1911	Heald and Wolf	
,, ,, ,,	Minnesota	1912	Stakman and Tolaas	Rosette and little potato (field)
,, ,, ,,	New Jersey	1912	Cook	Scurf
,, ,, ,,	N. Carolina	1912	Fulton*	
,, ,, ,,	New York	1913	Burkholder*	
,, ,, ,,	,, ,,	1913	Jagger*	
,, ,, ,,	Pennsylvania	1913	Orton*	Russet scab (field)
,, ,, ,,	Idaho	1914	Temple*	,, ,, ,,
,, ,, ,,	Maine	1914	Morse and Shapovalov	
,, ,, ,,	Alabama	1914	Wolf*	
,, ,, ,,	Washington	1914	Hall*	
,, ,, ,,	Oregon	1914	Bailey*	
,, ,, ,,	Montana	1914	Jennison*	Little potato (field)
,, ,, ,,	N. Dakota	1914	Bolley*	

*Personal letter.

TABLE 1.—*Continued*

Host	State	Date	Observer	Character of injury
Solanum tuberosum. Potato	Georgia	1914	Higgins*	Wilt (field)
,, ,, ,,	New Hampshire	1914	Butler*	
,, ,, ,,	Maryland	1914	Norton*	
,, ,, ,,	W. Virginia	1914	Giddings*	
,, ,, ,,	Utah	1914	Hill*	
,, ,, ,,	Vermont	1914	Lutman*	
,, ,, ,,	Kansas	1914	Melchers*	
,, ,, ,,	Wisconsin	1914	Jones	Black scurf (field)
,, ,, ,,	Michigan	1914	Coons	
,, ,, ,,	Illinois	1914	Peltier	Black scurf (field)
,, *verbascifolium*	Florida	1905	Rolfs	
Stachys lanata	Illinois	1914	Peltier	Damping-off, seedlings (greenhouse)
Taxus Canadensis. Yew	Connecticut	1912	Clinton	,, ,, ,,
,, *cuspidata*	,,	1912	,,	,, ,, ,,
Telanthera sp. Alternathera	Illinois	1912	Peltier	On mature plants (field)
,, ,, ,,	,,	1913	,,	Damping-off, cuttings (greenhouse)
,, ,, ,,	,,	1914	,,	,, ,, ,,
Trifolium pratense. Red clover	Colorado	1902	Rolfs	
,, ,, ,, ,,	N. Carolina	1911	Stevens and Wilson	Root rot (field)
,, ,, ,, ,,	Wisconsin	1914	Johnson*	,, ,, ,,
,, ,, ,, ,,	Ohio	1912	Arzberger*	,, ,, ,,
,, ,, ,, ,,	Utah	1912	Jensen*	,, ,, ,,
,, ,, ,, ,,	Minnesota	1913	Stakman*	,, ,, ,,
,, ,, ,, ,,	Illinois	1914	Peltier	Damping-off, seedlings (greenhouse)
,, ,, ,, ,,	,,	1914	,,	Root rot (greenhouse)
,, ,, ,, ,,	Kentucky	1914	Gilbert*	,, ,, (field)
Verbena sp.	New York	1901	Duggar and Stewart	Damping-off, cuttings (greenhouse)
Vigna catjang. Cowpea	Arkansas	1914	Hewitt*	Root rot (field)
Vinca major vars.	Illinois	1914	Peltier	Damping-off, cuttings (greenhouse)
Viola odorata. Violet	New York	1901	Duggar and Stewart	Stem rot (greenhouse)
,, ,, ,,	Illinois	1913	Peltier	,, ,, ,,
,, ,, ,,	Wisconsin	1912	Johnson*	Damping-off, seedlings (greenhouse)
,, *tricolor.* Pansy	Illinois	1914	Peltier	Stem rot (greenhouse)
,, ,, ,,	,,	1914	,,	Damping-off, seedlings (greenhouse)

*Personal letter.

TABLE 1.—*Concluded*

Host	State	Date	Observer	Character of injury
Vitis sp. Grape	N. Carolina	1911	Stevens and Wilson	Damping-off, cuttings (greenhouse)
,, ,, ,,	Georgia	1914	Higgins*	,, ,, seedlings ,,
Zea mays Corn	Florida	1905	Rolfs	
,, ,, ,,	Delaware	1912	Taubenhaus*	Damping-off, seedlings (greenhouse)
,, ,, ,,	Illinois	1914	Peltier	On roots (field)

*Personal letter.

TABLE 1a.—PLANTS REPORTED AS SUSCEPTIBLE TO *Rhizoctonia Crocorum* (PERS.) DC. IN THE UNITED STATES

Host	State	Date	Observer	Character of injury
Medicago sativa. Alfalfa	Nebraska	1890	Webber	Root rot (field)
,, ,, ,,	,,	1906	Heald	,, ,, ,,
,, ,, ,,	Kansas	1908	Freeman	,, ,, ,,
,, ,, ,,	Nebraska	1911	Heald	,, ,, ,,
,, ,, ,,	Virginia	1915	Reed and Crabill	,, ,, ,,
,, ,, ,,	Iowa	1915	Diehl**	,, ,, ,,
,, ,, ,,	Virginia	1915	Fromme**	,, ,, ,,
Solanum tuberosum. Potato	Oregon	1915	Bailey**	On tubers (field)
,, ,, ,,	Washington	1915	Rees*	,, ,, ,,

*Personal letter.
**Specimen received.

DISTRIBUTION OF RHIZOCTONIA IN CANADA

In a letter to the writer, Dr. H. T. Güssow of the Central Experimental Farm, Ottawa, Canada, stated that he had observed *Rhizoctonia Solani* on potato, pea, sweet pea, and aster. That the stem rot of carnation also occurs in Canada is shown in a paper read by John Morgan of Hamilton, Ontario, before the Canadian Horticultural Association at Guelph, in August, 1906.

DISTRIBUTION OF RHIZOCTONIA IN SOUTH AMERICA AND THE WEST INDIES

The following list of plants reported as susceptible to *R. Solani* in South America and the West Indies, with character of injury, has been compiled from Cook's[19] *Diseases of Tropicol Plants*:

Bean	Damping-off, dry rot of stem, and pod rot
Beet	Root disease
Cotton	Damping-off and sore shin
Cucumber	Damping-off
Lettuce	Damping-off
Melon	Damping-off
Nursery stock	Damping-off
Pea	Root and stem rot
Potato	On stem and tubers
Seedlings	Damping-off
Sweet potato	Root rot
Tobacco	Seed-bed rot
Tomato	Rosette and fruit rot

DISTRIBUTION OF RHIZOCTONIA IN EUROPE

Despite the wide distribution of Rhizoctonia in Europe, the nomenclature of the species is in a very confused state. Some writers understand *Rhizoctonia Crocorum* (Pers.) DC. to include several species, while others treat it as a separate species including forms with a rich violet mycelium. This uncertainty extends to the other common species of Rhizoctonia, so that the European literature on the subject offers many difficulties. Another fact which adds to the confusion is that both *Rhizoctonia Solani* and *Rhizoctonia Crocorum* attack potato stems and tubers, and while the symptoms caused by the two fungi can be easily distinguished from one another in the field, it is another matter to differentiate between them in literature.

A partial list of the hosts in Europe which are attacked by Rhizoctonia is given below to show the extent of the distribution of this fungus. Only the more important references are mentioned.

Austria Hungary.—Rhizoctonia was first reported in Austria Hungary in 1875 on potato. Later *R. Crocorum* was found on sugar beet, potato and lucerne, and *R. Solani* (*Corticium vagum*), on potato.

Belgium.—*R. Crocorum* has been observed in Belgium on sugar beet, potato, and asparagus.

Denmark.—E. Rostrup,[96-97] during the years 1884-1905, reported Rhizoctonia in Denmark on a large number of hosts, including many weeds and the roots of several species of forest trees. Among the cultivated crops mentioned are carrot, clover, lucerne, kohl-rabi, beet, turnip, sugar beet, and potato. Both *R. Solani* and *R. Crocorum* were observed on the potato. In 1892 Rostrup described a new species from turnip, which he called *Rhizoctonia fusca* and which differed only in one or two essential characters from *R. Crocorum*, also found on turnip.

England.—Rhizoctonia was first reported in England on mangel in 1901, and on potato in 1904. The next year Güssow,[48] in an extended account of this disease, stated that it was due to *R. Solani*. Salmon,[101] in working on a disease of seakale due to *R. Crocorum*, found that it was also able to attack salsify, parsnip, carrot, parsley, lettuce, and potato.

Finland.—Reuter[91] has studied a Rhizoctonia in Finland which causes a root rot of rye. *R. Crocorum* has been found on beet.

France.—Between the discovery of *R. Crocorum* in France in 1728, on crocus, and 1851, a number of hosts, including asparagus, bean, clover, *Citrus*, *Coronilla*, grape, onion, *Rubia*, *Sambucus*, and tulip, were reported.

Germany.—In 1858 Kühn[64] found *R. Crocorum* on sugar beet in Germany and described the species *R. Solani* on potato and carrot.

Eriksson[38] states that in Germany in 1893 *R. Crocorum* appeared on sugar beet in several places; on lucerne, in 55 localities on plants 1 to 5 years old; on potato, in 11 localities; on asparagus, in 3 localities; on hop, in 1 locality; and also on a few weeds, such as *Taraxacum officinale*, *Convolvulus arvensis*, etc.; and that in 1894 it was observed on lucerne, in 77 localities; on potato, in 11 localities; and on red clover, in 8 localities. The species *R. Solani* (*Corticium vagum*) and *R. Strobi* Scholtz on white pine, have been recorded.

Holland.—Dr. Johanna Westerdijk reports both *R. Crocorum* and *R. Solani* as being very abundant on potato in Holland.

Ireland.—*Pethybridge* [83-55] has shown that both *R. Crocorum* and *R. Solani* are present on potato in Ireland.

Italy.—*R. Crocorum* has been reported at various times as present on alfalfa, sugar beet, clover, asparagus, carrot, parsley, chard, the roots of grape, and many weeds in Italy. *Rhizoctonia destruens* Tassi occurs on the roots of *Delphinium*.

Portugal.—The Rhizoctonia attacking sugar beet has been reported from two localities in Portugal.

Russia.—*R. Solani* was reported on potato in Russia in 1899.

Sweden.—Eriksson[37-39] observed a disease of carrot and beet in 1898 in Sweden, caused by *R. Crocorum.* He was able to inoculate this fungus on garden and sugar beet, alfalfa, potato, and many weeds —*Stellaria media, Myostis arvensis, Galeopsis, Tilrahit, Erysimum cheiranthoides, Urtica dioica,* and *Sonchus* sp. In addition to these hosts Eriksson has reported *R. Solani* (*Corticium vagum*) on potato and *R. Crocorum* on turnip and kohl-rabi.

DISTRIBUTION OF RHIZOCTONIA IN INDIA AND AUSTRALIA

Shaw,[109] working on the morphology and parasitism of Rhizoctonia in India, reported *Rhizoctonia Solani* on peanut (*Arachis hypogoea*), cowpea (*Vigna catjang*), jute (*Corchorus capsularis*), *Dolichos Lablab, Trichosanthes cucumernia,* soybean (*Glycine soja*), mulberry (*Morus alba*), sesame, melon roots, cotton, roots of *Agave rigida,* and potato.

In Australia, McAlpine[67] found *R. Solani* very widely distributed on potato.

PLAN OF PROCEDURE

The main object of the present research was to determine whether of the culturable forms of Rhizoctonia one or more than one race or species is present in this country. The work was taken up from the following standpoints:

1. Symptoms of Rhizoctonia disease on various hosts
2. Inoculation experiments
3. Growth on media
4. Measurement of mycelial cells
5. Soil survey

SYMPTOMS OF RHIZOCTONIA DISEASE ON VARIOUS HOSTS

Following are presented the observations of the writer concerning the nature of the diseases caused by Rhizoctonia on the various hosts, together with the principal facts which appear in literature regarding Rhizoctonia on the more important crop plants in this country.

ALFALFA, *Medicago sativa*

On March 17, 1914, the attention of the author was called to the damping-off of young alfalfa seedlings in the agronomy greenhouse of the Station. Microscopic examination and pure cultures showed it to be due to Rhizoctonia. The seeds had been sown in rows in pure quartz sand and kept well moistened. The young seedlings, on germination, were somewhat crowded, so that the conditions were very

favorable for damping-off. The fungus could be seen extending in all directions over the surface of the sand.

The fungus found on the diseased alfalfa seedlings was compared with a fungus obtained from mature alfalfa plants sent from Iowa. Altho the mycelium of the two forms was characteristic of Rhizoctonia, it differed in many respects, particularly in the color of the hyphæ. The form on the mature plants was undoubtedly *Rhizoctonia Crocorum*, while that on the seedlings was the common *Rhizoctonia Solani*.

Rhizoctonia was first reported on the roots of alfalfa from Nebraska in 1890, by Webber,[137] as *Rhizoctonia Medicaginis* DC. This fungus was next mentioned on alfalfa as *Rhizoctonia violacea*, by Heald,[57] who found it causing a root rot in a single locality in Nebraska in 1906. In 1908 it was reported by Freeman,[42] under the name *Rhizoctonia violacea*, as spreading rapidly in the alfalfa fields in Kansas. Freeman described the disease as beginning in different parts of the field where at first a single plant dies. From these centers of infection the fungus grows in all directions thru the soil, killing the plants as it proceeds. Thus circles of steadily increasing radii are formed, at the edges of which plants in all stages of the disease are found. The great majority of the plants within the affected areas die, while those which survive are not vigorous and always lose their main tap roots.

The first external sign of the disease is a yellowing of the plant, which soon after wilts and dies. The roots of a dead or dying plant are found to be covered with a violet or brownish red mat of mycelial strands, or hyphæ. In a few cases the tap root is completely rotted. In less severely affected plants, the cortex of the roots slips off easily when the plants are lifted from the soil, leaving only the central woody cylinder. This condition is due to the fungous threads which grow thru the cortex as far as the cambium layer, which they kill. The fungus forms sclerotia, which may live in the soil for several years.

Stewart[126] in 1908 mentioned a root rot and damping-off of alfalfa in the field in New York. His description of the disease agrees in some respects with the one given by Freeman. Later he also noticed the damping-off of alfalfa seedlings in the greenhouse. He was not certain that *Rhizoctonia Crocorum* was present in New York, and was of the opinion that the fungus causing the damping-off of seedlings in the greenhouse was different from the one found in the field.

Heald,[58] in a later article (1911), described more fully the disease occurring in Nebraska. At that time he regarded the fungus as identical with *Rhizoctonia Medicaginis* DC. of Europe.

From the above accounts it is certain that there are two species of Rhizoctonia in this country able to attack alfalfa—*R. Solani*, widely distributed, causing only a damping-off of seedlings, and *R. Crocorum*, with a limited distribution, attacking as a rule only mature plants in the field. At present this latter species has been reported on alfalfa from Nebraska, Kansas, Iowa, and Virginia.

ALTERNANTHERA, *Telanthera* sp.

In the fall of 1912 cuttings from alternanthera, coleus, and salvia plants which had been placed in the same bench were found to be damping-off. A microscopic observation and pure cultures from diseased cuttings showed that *Rhizoctonia Solani* was the causal organism. Later the fungus was found on alternanthera plants in the field, but apparently it caused no injury there.

Alternanthera plants grow low and bushy, and thruout the summer, no matter how dry the season, the soil underneath is usually moist. On close examination of the tangled mass of branches, strands of a fungus, which were later found to be made up of bundles of hyphæ, could be seen spreading in all directions. At first glance the masses of mycelium looked very much like old spider webs. A number of different varieties of alternanthera were examined, and all were found to have the characteristic brown strands ramifying upon the surface of the whole under side of the plant. The reddish varieties seemed to have more of the fungous strands than did the green and variegated plants. Cultures from the brown strands in every case yielded pure cultures of Rhizoctonia which corresponded morphologically and physiologically to the Rhizoctonia obtained from the cuttings.

Whether the fungus was at any time parasitic on the plants in the field was questionable. However, cuttings made from them still contained pieces of mycelium, and when placed in sand in the greenhouse, the fungus did parasitize not only the alternanthera cuttings but others as well.

The belief that Rhizoctonia is present on the branches of the alternanthera plant thruout the year was corroborated in 1913 and again in the fall of 1914, when the cuttings made from plants in the field began to damp off in the cutting bench. Repeated observations showed that the fungus was present on the plants in the field, notwithstanding the fact that they had been planted in new soil. Old plants brought in from the field were cut close to the roots and planted in flats in the greenhouse. These sprouted and developed new shoots, from which cuttings were made. Many weeds came up in the flats during the winter, and in March both the cuttings and the weeds became infected with Rhizoctonia. It seems, therefore, that the fungus is present on alternanthera at all times of the year, tho the only injury it causes is damping-off of cuttings in the greenhouse.

ALYSSUM, SWEET, *Alyssum odoratum*

During June, 1914, when the bedding and decorative plants were being set out from the floricultural greenhouses of the Station, about

twenty-five plants of sweet alyssum growing in two and one-half inch pots were found to be diseased. The plants were tall and had fallen over from their own weight, so that they formed a mat over the pots. On close examination the soil and plants were found to be covered with the strands of brown mycelium which are characteristic of *R. Solani*. A number of these plants died, while on the stems of others the fungus formed small lesions near the surface of the soil. The fungus continued to grow on diseased plants placed in the field, and killed a few more of them.

AMARANTHUS

Specimens of Rhizoctonia on *Amaranthus retroflexus* were received from Mr. W. H. Burkholder of Cornell University. The mycelium of the Corticium stage could be easily recognized on the stems, while the Rhizoctonia stage was plentiful on the lower part of the plant. A culture was obtained from scrapings made from the mycelium of the Corticium stage. Several spores were found and one basidium showing the four sterigmata was observed.

Duggar and Stewart[32] reported the occurrence of Rhizoctonia on *Amaranthus retroflexus* (pigweed) and *A. albus* (tumble-weed) in New York in 1901. Several years later Rolfs[95] found the perfect stage, *Corticium vagum*, in Florida on *A. retroflexus* and *A. spinosus*.

ASPARAGUS, ORNAMENTAL, *Asparagus sprengeri*

Duggar and Stewart[32] observed the effects of Rhizoctonia on a number of plants of ornamental asparagus. They found that the plants were killed and that many of the leaves were bound to each other by the brown threads of the Rhizoctonia hyphæ.

ASTER, CHINA, *Callistephus hortensis*

Damping-off of aster seedlings was noticed in flats in the floricultural greenhouses in the spring of 1913 and again in 1914. The disease first appeared as a small, brown spot on one side of the seedling at the surface of the soil. This lesion increased in size until the seedling fell over. After a number of seedlings were prostrated, the fungus spread over them, and in time a mat of mycelium covered the surface of the soil.

In May, 1914, a number of aster plants, four to five inches high, were planted in old soil in which several varieties of carnation plants had been growing during the winter. There had been more or less stem rot among these plants all the season. After a month, when the aster plants were about 6 inches high, they began dying off and continued to die until they were from 9 to 12 inches high and ready to

bud. Other aster plants set in new soil at the same time that these were transplanted developed normally with no stem rot whatever.

TABLE 2.—MORTALITY OF DIFFERENT VARIETIES OF ASTER GROWN IN OLD CARNATION SOIL INFECTED WITH *Rhizoctonia Solani*

Variety	Number of plants	Total dead	Total healthy
Queen of the Market	50	1	49
Lavender	50	1	49
Azure Blue	50	4	46
Purple	50	7	43
Pure White	100	13	87
Shell Pink	50	2	48
Rose Pink	50	0	50
Deep Rose	50	0	50
Crimson	50	1	49

As can be seen from Table 2, plants from all but two of the varieties died in the bench. The varieties Azure Blue, Purple, and Pure White were planted where most of the stem rot on the carnations occurred; hence the higher number of diseased plants in those varieties is due to location rather than to varietal susceptibility to Rhizoctonia.

Obviously the Rhizoctonia causing carnation stem rot was in this case able to attack healthy aster plants. The stem rot of these plants was typical and very similar to the rot of carnations. The first sign of the disease was a yellowing and drooping of the foliage, followed, sooner or later, depending on weather conditions, by a sudden wilting of the whole plant. When the plant was pulled, the bark of the stem near the surface of the soil would slough off, leaving only the discolored woody tissues.

A stem rot of aster due to Rhizoctonia has been reported only once before in this country. Duggar and Stewart[32] in 1901 found the mycelium in the tissues of aster and later isolated a pure culture from them. They observed the disease in a number of localities in New York during that summer.

BEAN, *Phaseolus vulgaris*

The damping-off of young bean seedlings by *R. Solani*, which has been observed in the greenhouse and in the field, is characterized by the production of small lesions at the surface of the ground either on one side of the stem or girdling it, followed by the falling over and death of the seedling.

When the fungus attacks older bean plants, lesions of various sizes are produced just below the surface of the ground, at the surface, or one or two inches above it. In some plants these discolored spots can be found on the larger roots also. The lesions, as a rule, have a

FIG. 8.—STEMS OF MATURE BEAN PLANTS WHICH HAD BEEN PLACED IN A BENCH INFECTED WITH *Rhizoctonia Solani* ORIGINALLY OBTAINED FROM CARNATION PLANTS

reddish brown band with a lighter colored, sunken area, and extend thru the cortical layer into the woody tissues. As on the young seedlings, the spots are usually localized on one side of the stem, but in some cases one lesion may girdle the plant. These lesions weaken the stem and cause it to break off easily.

The first account of Rhizoctonia causing a disease of bean was given by Atkinson.[4] He reported that during the winter of 1894-95 it caused damping-off of bean seedlings and attacked plants that were from 6 to 10 inches high. He referred to this form as "the sterile fungus," and stated that its most characteristic peculiarity was the mode of branching.

In 1901 Duggar and Stewart[32] reported this fungus, from New York, as the cause of a stem-rot disease of red kidney beans in the field and of a damping-off among seedling beans in the greenhouse.

In 1904 Hedgcock[60] reported as follows:

"The bean crop in the vicinity of St. Louis was severely injured by a Rhizoctonia which attacked the stems and large roots of the plant and also produced brown sunken areas on the surface of the pods, penetrating the latter and discoloring the seeds. An examination of a number of seeds whose surface was discolored, disclosed the fact that the mycelium of the fungus had established itself in the second coat and in many instances had formed minute sclerotia there without rotting the seed or even penetrating the cotyledons. The presence of the fungus did not prevent the germination of the seed."

Fulton[44] in 1908 showed that Rhizoctonia from infected pods caused damping-off of seedling beans and of month-old plants.

A serious outbreak of the stem rot of beans was reported from New York by Barrus[9] in 1910. He found that in some fields as many as 30 percent of the plants were infected. In the same fields during the following season it caused the death of at least 5 to 6 percent of the seedlings; later in the season, after a rainy spell, a large percentage of the pods in contact with the ground became infected.

BEET, *Beta vulgaris*

Young seedlings of the garden beet, in flats, were found damping off in the vegetable-gardening greenhouses of the Station, July 10, 1913. Cultures showed that *R. Solani* was the sole cause of the disease. Characteristic lesions were found on the beets at the surface of the ground, and strands of mycelium could be plainly seen spreading out on the surface of the soil.

As with root rot of other fleshy crops, the fungus gains its first hold at the crown of the mature plant, which, as a rule, is just below the surface of the ground. The first evidence of the disease is a darkening of the leaf bases, followed by the rotting of the crown. The leaves retain their color for a long time, or until the leaf stalks rot off almost completely. With the rotting at the crown, the beets begin to crack from this point. While the tissues around the cracks remain firm, as a rule, for a long time, the crown is usually soft, a condition due to the entrance of other organisms. Lesions are sometimes formed on the sides of the beets, often extending deep into the tissues. When weather conditions become unfavorable to the fungus, the rotting and cracking stops and the plant may recover from the attack. The disease is generally scattered thru the field, only a few plants in a given area being affected.

Under the name *Rhizoctonia betæ* Kühn, Pammel[76] in 1891 described a root rot of sugar beets. He was the first investigator to report serious damage caused by Rhizoctonia in this country. Duggar[28] in 1899 regarded the root-rot disease of sugar beet due to Rhizoctonia as one of the important diseases of that plant. At the present time this disease is very widespread and is the cause of considerable loss, especially in irrigated regions.

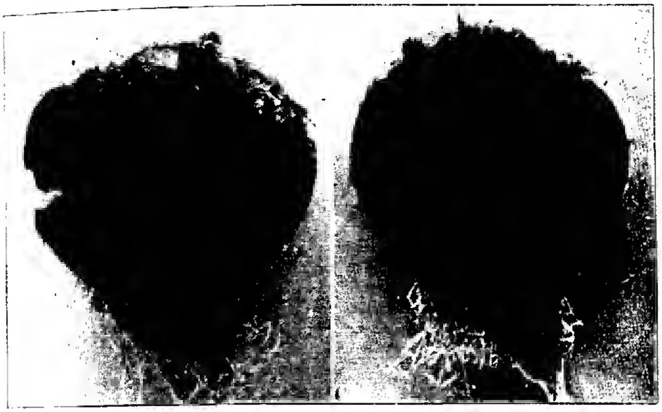

FIG. 9.—GARDEN BEET INOCULATED WITH *Rhizoctonia Solani* FROM CARNATION, SHOWING A LATE STAGE OF INFECTION (Experiment 8)

Damping-off of sugar-beet seedlings has been reported by Selby,[108] from Ohio, and by Smith,[113] from California.

BEGONIA

Mr. H. W. Anderson in 1911 found a number of begonia cuttings in the floricultural greenhouses that were damping off badly because of Rhizoctonia infection. The symptoms were similar to those described for cuttings of alternanthera.

Damping-off of begonia cuttings has also been observed in New York by Duggar and Stewart,[32] and in North Carolina by Stevens and Wilson.[122]

BLACKBERRY, *Rubus* sp.

Root disease of blackberry and raspberry caused by Rhizoctonia has been reported only once in this country. Paddock [75] of Colorado, who studied this disease, described it as follows:

"The trouble was first noticed by the foliage becoming light green or yellowish. Later in the season leaves on occasional plants began to curl and shrivel as parts of the plant below ground were attacked, but the greatest injury occurred on the canes above the crown. Here the bark was discolored and shrunken from the crown to the surface of the soil, or a short distance above. The fungus grew out within the bark, destroying the tissues, and interfering with the movements of plant food. The injury commonly extended around the cane, and when it became deep enough to cut off the supply of moisture and food, the plant died."

BUCKWHEAT, *Fagopyrum esculentum*

In 1911 Stevens and Wilson[120-121] mentioned a serious outbreak of Rhizoctonia on buckwheat in the western part of North Carolina. No description of the disease was given.

CABBAGE, *Brassica oleracea*

Atkinson,[4] in 1895, in his article on damping-off diseases, mentioned cabbage seedlings as being susceptible to damping-off by Rhizoctonia.

Duggar and Stewart[32] in 1898 received from Illinois specimens of cabbage seedlings which had been diseased by Rhizoctonia. They found that the disease sometimes affected very young seedlings, causing damping-off, but that it was more common after the plants had developed one or two true leaves. In the latter instances, small lesions at or below the surface of the soil characterized the disease. Later, Duggar and Stewart found Rhizoctonia causing a similar disease of cauliflower seedlings in New York. The plants showed ulceration at the bases of the stems, the entire cortex in some cases having disappeared.

Fawcett[40] reported a stem rot of cabbage seedlings due to *Corticium vagum* B. & C., in Florida, in 1909. According to his description, the disease was a typical stem rot, with a softening of the epidermis followed by a shriv-

FIG. 10.—STEMS OF YOUNG CABBAGE PLANTS INOCULATED WITH *Rhizoctonia Solani* FROM CARNATION

FIG. 11.—STEM OF AN OLD CABBAGE PLANT WHICH HAD BEEN PLACED IN A BENCH INFECTED WITH *Rhizoctonia Solani* FROM CARNATION (Experiment 9)

ling of the outside tissues and a browning of the leaves. However, the plants so affected did not wilt down entirely, and many of them recovered.

CANDYTUFT, *Iberis* sp.

During June, 1914, a few plants of candytuft that had been growing in three-inch pots in the floricultural greenhouses, rotted off at the surface of the ground. The symptoms were similar to those described for sweet alyssum. Microscopic examination of diseased tissue revealed *R. Solani* in every case. Dense masses of hyphæ covering the leaves and stems of these plants were plainly visible.

Duggar and Stewart[32] in 1901 reported damping-off by Rhizoctonia of cuttings of candytuft in New York.

CARNATION, *Dianthus caryophyllus*

Rhizoctonia Solani attacks carnation plants of all ages, both in the field and in the greenhouse, causing not only stem rot, but damping-off of cuttings, of which it is one of the principal causes.

The symptoms of stem rot of carnation are very characteristic of the effects of *R. Solani* (Fig. 1). The fungus usually attacks the stem of the plant at the surface of the ground or occasionally just above or below. As a rule, the first indication of the disease is a pale green color of an entire plant or of a single branch. This lighter color can be noticed in most cases for several days before the actual wilting takes place. During cloudy weather the plant does not wilt for two weeks and sometimes for even longer, altho the stem may be almost completely rotted; in sunny weather wilting occurs much sooner.

If the stem of a plant that shows the first sign of wilting is pressed just at the surface of the soil, a soft place is felt and a slight twist is sufficient to slough off the bark. Beneath this is a slimy, wet area, which gives this rot its characteristic name. Sometimes, however, the stem is dry at the point of attack, and upon being broken off, the fibers appear to be separated and stringy.

The fungus enters the cracks in the corky layer of the bark and attacks the cambium layer, causing the sloughing off of the bark. It then penetrates the woody tissues, and can be found even in the pith. The plant may remain alive after the cambium layer is destroyed until the fungus plugs the vessels. If a diseased plant is left in the soil for some time, the mycelium overruns the stem, and dark, round sclerotia are formed either directly on the bark or in the crevices, or cracks.

The Rhizoctonia disease of carnation has been known to florists ever since carnations have been grown as a commercial crop in the greenhouse. In Volume I of the *American Florist,* 1886, is found the following paragraph, which is probably the first published statement concerning the stem rot of carnation in this country.

"In a few days plants began to show signs of wilting, and upon examination I found them rotted off just at the top of the ground, tho half an inch under the ground the stems appeared perfectly healthy."

FIG. 12.—CARNATION CUTTINGS SHOWING DAMPING-OFF CAUSED BY *Rhizoctonia Solani* (Experiment 1)

While the cause of the disease was not known at that time, from the description of the symptoms it is not to be doubted that it was due to Rhizoctonia.

A great loss of plants from stem rot occurred thruout the country about 1900. Below are given a few excerpts from notes on this disease which have appeared during the last thirty years, some of which agree with our present-day ideas:

1886. "Deep planting causes the disease in many houses."

"In our opinion high temperature and deep planting have much to do with the disease."

1898. "The most dangerous disease that attacks the carnation. Some varieties appear more subject to this disease than others, and there is considerable complaint about Flora Hill and Silver Spray this season. The most common error that very often leads to this disease is too deep planting. The plants should never be planted deeper than they stood in the field, preferably not so deep. The stem of the plant should be out of the ground sufficiently to hold the branches away from the soil. I believe this disease is not found on carnations alone, but on other plants too, and the spores of this fungus may have been embedded in the soil, carried over or imprisoned, dormant in the plant from the cutting bench.

"To check and prevent the spreading of this disease, dust flour of sulfur over the plants, and shake them so it will lodge on the stem and branches and on the soil around the stem."

1900. "Climatic conditions rather than anything else are the chief causes of the trouble. High ranges of temperature whether in the cutting bench, field, or house, the results are the same, the amount of rot varying with preceding conditions. Thus, after heavy rains inducing soft growth, a rise of temperature into the 90's is a capital condition for the development of stem rot. Some varieties are also more susceptible to attacks than others, the woodier ones being able to withstand it more than those of soft growth."

1904. "Stem rot is due to allowing plants to become pot-bound.

"Rich soil with too much manure causing a rapid growth causes stem rot. I believe this to be responsible for more stem rot than all other conditions combined. Too deep planting also favorable for stem rot. Water when absolutely necessary and then water thoroly."

1906. "Presence of wounds on the bark, or punctures made by insects; faulty planting; sour or too highly enriched soil; lack of drainage; careless cultivation; lack of fresh circulating air; the maintenance of too great heat combined with atmosphere heavily charged with stagnant moisture during the time when the outdoor stocks are housed, will cause stem rot to become severe in the benches."

1907. "Stem rot is the most dreaded and only disease of carnations in the South."

1909. "Stem rot more dreaded in South than in North."

1911. "Fresh air, plenty of circulation, a sweet soil, and proper watering will avoid to a great extent the appearance of stem rot or stop its spread. Weather conditions seem to play an important part, and in most cases as soon as cold nights are the rule, our troubles grow less. The greatest benefit is derived thru a clear and rather dry atmosphere. Deep planting not so important. Too much manure not necessarily a cause of stem rot.

"Stem rot is more prevalent in sour soils than others. The surface of the soil should be kept open by frequent scratching. A dry interior and a wet surface is very conducive to stem rot."

1913. "Stem rot in the South is more serious than in the North."

The following older carnation varieties have beeen reported as being especially susceptible to stem rot: La Purjté, Crimson King, De Graws, Sewan, Flora Hill, Silver Spray, McGowan, Portias, Scott, Jubilee,

Craig, Boston Market, Crane, Lawson, Lady Bountiful, Winsor. Several of these varieties are still propagated by a few growers and with good success, but the majority of them have been discarded. Of the newer types no one seems to be more susceptible than the others.

To Duggar and Stewart[30] is owed the discovery that Rhizoctonia is the cause of stem rot of carnation. This they proved conclusively in 1899 by inoculation experiments with pure cultures, repeated many times. Duggar and Stewart state that this stem rot is one of the most troublesome of the carnation diseases and probably occurs thruout the United States wherever the carnation is grown. Stewart[123,124] at the same time distinguished between two distinct diseases, both called "stem rot." One is caused by Rhizoctonia, and the other by Fusarium.

Card and Adams[13] of Rhode Island studied methods of control of both Fusarium and Rhizoctonia rots. They came to the conclusion that the use of clean, fresh sand in the cutting bench helps to control the fungus. They also found that stable manure does not favor the spread of the disease.

In 1902 Stone and Smith[129] reported carnation stem rot in Massachusetts. Two years later Clinton[14] reported the presence of the disease in Connecticut. In 1906 Heald[57] stated that it was found in the field and in the greenhouse near Lincoln, Nebraska. Blake and Farley[10] in New Jersey conducted a number of soil experiments for the control of stem rot.

CARROT, *Daucus carota*

Occasionally *R. Solani* causes damping-off of carrot seedlings, but the plants seem to be more susceptible later, when the fleshy root is formed. Here the rot starts at the crown and works up into the leaf bases. It also progresses into the interior of the fleshy root, as a rule showing no signs on the exterior for some time. In some cases lesions are found on the exterior of the carrot and on the larger secondary roots where they branch from the fleshy part.

Duggar and Stewart[32] were the first to find a disease of carrot due to Rhizoctonia. In 1911 Heald and Wolf[59] reported from Texas the Corticium stage of the fungus on carrot. They stated that the roots were covered by white, ropy strands of the fungus, but that no serious rotting was observed.

CELERY, *Apium graveolens*

A damping-off of celery seedlings in flats by *Rhizoctonia Solani* has been observed in the Station vegetable-gardening greenhouses. The symptoms are similar to those described for beets.

During a search in the market in the winter of 1914 for leaf spot and soft rot on celery, several bunches shipped from New York were

found to have a brown mycelium and many small sclerotia between the stalks near the base. The fungus was causing no injury to the celery. When examined in the laboratory, the mycelium and sclerotia proved to be those of Rhizoctonia. Pure cultures of the fungus were obtained readily from the sclerotia. Repeated examinations of new shipments of celery from New York showed that in the majority of cases Rhizoctonia was present between the stalks.

Duggar and Stewart[32] in 1901 were the first to report Rhizoctonia causing a destructive damping-off of celery seedlings. Rolfs[95] in 1905 reported a damping-off of seedlings in Florida caused by *Corticium vagum* B. & C. Van Hook[136] found a Rhizoctonia associated with a root rot of celery in the field. He did not believe, however, that this fungus was the cause of all the trouble. Affected plants never attained full size, and an examination of the roots showed considerable decay. The disease seemed to affect the main roots, which rotted off rapidly near the crown. The fact that seed beds in new soil did not entirely control the trouble showed that the fungus Rhizoctonia was present in the new soil, tho not in any great amounts. Halligan,[51] in Michigan, has also studied the damping-off of celery plants in the seed bed.

Centaurea gymnocarpa

In the spring of 1914 a large number of seedlings of *Centaurea gymnocarpa,* including some of those which were potted, damped off. By June many of the potted plants were dying with stem rot, the disease having been carried over on affected seedlings and in a few cases, no doubt, on healthy ones. Microscopic examination and pure cultures showed that in each case *R. Solani* was present in the diseased tissues. The progress of the disease was rather typical. The first symptom was the wilting and drying up of the foliage. On pulling up the plant, a number of the leaves were seen to be rotted off at the crown, while the bark on the stem below the surface of the ground sloughed off and the tissues beneath were wet and stringy.

CLOVER, RED, *Trifolium pratense*

In the spring of 1914 damping-off of red and Japanese clover was observed in the agronomy greenhouses. A culture easily obtained from the fungus appeared to be the same in all respects as the one isolated from alfalfa seedlings which were growing under similar conditions in close proximity.

Stevens and Wilson [122] in 1911 reported that in a field of clover in North Carolina the roots were being attacked by Rhizoctonia and were suffering some damage. This is the only instance in which Rhizoctonia has been reported as injuring clover in the field.

COLEUS, *Coleus* sp.

In November, 1912, cuttings of coleus began to damp off in a bench in the floricultural greenhouses. The variegated green varieties seemed more susceptible to the fungus than the variegated red and yellow. The trouble was found to be due to *R. Solani.* The infected cuttings showed characteristic lesions on the stems at the surface of the sand. These lesions were quite large and distinct, brown in color, and depressed several millimeters at the center. They were generally found on one side, but in some cases the whole cutting was girdled. Practically all the coleus cuttings in the bench damped off in this manner.

During October, 1913, Rhizoctonia was found causing a damping-off of coleus seedlings planted very close in flats. About half the plants damped off.

Duggar and Stewart[32] reported a damping-off of coleus cuttings in New York, caused by Rhizoctonia, similar to that observed at this Station.

CONIFEROUS SEEDLINGS

The first case reported of damping-off of white-pine seedlings due to Rhizoctonia was by Duggar and Stewart,[32] from New York. Ten years later Clinton[17] mentioned the damping-off of a number of coniferous seedlings.

Hartley,[55] who made a study of the damping-off of coniferous seedlings in the West, found that Rhizoctonia is one of several organisms involved. He wrote as follows:

"Rhizoctonia (probably *Corticium vagum* B. & C.), which causes damping-off of very young seedlings, sometimes continues to work in patches till the plants are two months old or even more On sandy soil, when seedlings from five to nine weeks old are killed, the youngest and deepest parts of the roots are usually first attacked. At Halsey, roots of Rocky Mountain yellow-pine seedlings about seven weeks old have been attacked at points as much as eleven inches below the ground surface. In many plants as old as this the older parts of the roots resist the entrance of the fungus which has rotted the younger parts and throw out new root branches, so that recovery takes place without any evidence of the damage being shown by the plant above ground."

Coreopsis lanceolata

Duggar and Stewart[32] in 1901 mentioned the fact that next to a plot of sweet williams that were being killed by Rhizoctonia, were two rows of *Coreopsis lanceolata* which were also diseased. They stated that "only a few plants were killed, but from many of them the lower leaves had rotted away. The rot seemed to start in the base of the petiole, where it came in contact with the soil. The decaying leaves were overrun with Rhizoctonia."

CORN, *Zea mays*

In 1914, during the progress of the soil survey for *R. Solani*, the fungus was found frequently on corn roots in the field. It could not be determined whether the fungus penetrated the roots or not, but there was no question as to the abundance of the mycelium on the roots.

Rolfs[95] in 1905 reported *Corticium vagum* B. & C. on corn in Florida.

COTTON, *Gossypium herbaceum*

Glover[46] in 1855 described a sore shin of cotton, which in some respects is the same as the disease of seedling cotton caused by Rhizoctonia. He stated that "the cause is attributed by many to cold, cutting winds, when the plant is very young. Others, however, assert that when a high wind shakes a tender plant, the main stem is so much bent and twisted that the sap vessels are upturned and a serious injury occurs."

FIG. 13.—STEMS OF YOUNG CARNATION PLANTS INOCULATED WITH RHIZOCTONIA FROM COTTON, SHOWING LESIONS CHARACTERISTIC OF SORE SHIN OF COTTON CAUSED BY THE SAME FUNGUS

One of the causes of sore-shin disease of cotton remained undiscovered until Atkinson,[5] in 1896, found in the diseased tissues a sterile mycelium, which he later identified as Rhizoctonia. By means of pure-culture methods and inoculation experiments he further proved that this sterile fungus was the cause of sore shin and also of seedling rot and damping-off of cotton. He describes the Rhizoctonia disease of cotton as follows:

"There are several phases of the disease. Sometimes the tissues undergo a soft rot which progresses very rapidly, and the early stages are not marked by any striking color characteristics. Another phase may progress rapidly or slowly and is usually quite well characterized by a reddish brown color which accompanies it. This phase is also characteristic in that it is usually manifested on one side of the stem in the form of an ulcer which gradually deepens until the vascular system is reached, when the life of the plant becomes really endangered. Even when this stage is reached, however, the plant may, and does frequently, recover.

"This latter phase is characteristic of a very common disease of seedling cotton. It is called by the planters in many places 'sore shin.'

"The diseased portion of the plant is just beneath the surface of the ground and presents an area of shrunken tissue of a dull brown or reddish color. The

size of the shrunken area and the depth of the injury are proportionate to the serious condition of the ulcer, as it may be termed. If the injury remains confined to the superficial tissues, the plant will usually recover. It does sometimes recover when the injury reaches the vascular tissue, but more frequently death results when the trouble has progressed thus far."

No further original work has been done on this disease since the time of Atkinson, altho several of the southern experiment stations have published bulletins on cotton diseases, including the sore shin and seedling rot due to Rhizoctonia.

Dianthus

R. Solani was isolated from diseased plants of *Dianthus barbatus* (Newport Pink), during July, 1913, in the perennial garden of the Station. This variety and *Dianthus barbatus* (single mixed) were much more susceptible to stem rot than were any of the other varieties grown. In fact, practically every plant of these two varieties died from stem rot during the summer. These varieties are more like the carnation than any of the others, and when affected, the symptoms of the disease were very similar to those of stem rot of carnation. The first evidence of the disease was the pale green color of the leaves, followed in many cases by a sudden wilting of the foliage. When plants in this stage were pulled up, the bark readily sloughed off, leaving the wood exposed. When plants in the later stages of the disease were pulled up, the stem usually broke off at the surface of the ground, exposing stringy tissue.

During the same month, a disease of *Dianthus sequeri* and *D. plumarius* was under observation. Diseased parts of these plants yielded Rhizoctonia in every instance. In the case of *D. sequeri* the fungus seemed to be living saprophytically among the numerous prostrate, bushy branches. The brown strands of the mycelium could be plainly seen running thru the bushy mass of the plant. Only a few plants died. Unlike the case of *D. barbatus*, there was no characteristic sloughing off of the bark, but a more or less general rotting of the whole stem, which left the tissues very dry and stringy. The attack was not confined to the main stem, but affected any of the branches which touched the ground.

Most of the plants of *D. plumarius*, occupying a space about three feet long, died from attacks of the fungus. The symptoms of the disease were very similar to those of *D. sequeri*, the rotting appearing to extend gradually from one point thru the whole stem. As with *D. sequeri* also, the bushy habit of the plant gave ample protection to the fungus, and the radiating strands of the brown mycelium of Rhizoctonia were visible to the naked eye.

Duggar and Stewart[32] in 1900 found a badly diseased plot of *Dianthus barbatus* in which 90 percent of the plants, in the course of the season, died from stem rot due to Rhizoctonia.

EGGPLANT, *Solanum melongena*

During August, 1912, while some field observations were being made on carnation stem rot, the fruits of a number of eggplants in an adjoining field were found to be rotting at the point where they touched the ground. The decay spread in all directions from this point, making a sunken, brown area; this was followed by the softening and subsequent collapse of the surrounding tissues. Fruits showing this decay were brought into the laboratory and placed under a bell jar. Around the diseased spot there soon developed a thick mass of mycelium, which on microscopic observation was found to consist of hyphæ of Fusarium and Rhizoctonia. The decaying spots contained no fungous threads, but were completely filled with bacteria. On plating, pure cultures of *R. Solani* were obtained. The cause of the primary infection is not known. It is very probable that both the Fusarium and Rhizoctonia entered the tissues where the epidermis had been destroyed.

In July, 1913, the damping-off of a number of eggplant seedlings in the vegetable greenhouses was noticed. This was shown, by pure cultures of the diseased material, to be due entirely to Rhizoctonia. The fungus produced the characteristic lesions on one side of the seedlings at the surface of the soil, causing the stem to break.

Atkinson,[4] in his account of damping-off diseases, mentioned eggplant seedlings among those susceptible to attacks of the sterile fungus (Rhizoctonia). Rolfs[95] reported the presence of the Corticium stage of Rhizoctonia on mature plants in an irrigated garden. Here the plants affected drooped for a time and then wilted and died. Lesions were formed on the stems at the surface of the ground. Wolf[140,141] in 1914 reported damping-off and a fruit rot of eggplants due to Rhizoctonia (*Corticium vagum* B. & C.), but he does not regard the fungus as the cause of serious injury to eggplants.

FIVE-FINGER, *Potentilla* sp.

A number of five-finger plants were found to be infected with *R. Solani* during June, 1914, in inoculated sections in the floricultural greenhouses. The mycelium of the fungus was present at the nodes which touched the soil and also at the bases of the plants, where crown rot was developing.

FOXTAIL GRASS, *Setaria glauca*

Several plants of foxtail grass growing under the same conditions as the preceding host, five-finger, showed a root infection.

Gypsophila repens

A number of *Gypsophila repens* plants were found diseased in the herbaceous grounds during July, 1913. Pure cultures of the diseased

material showed the causal organism to be *R. Solani.* The plants were bushy, so that some of the branches and leaves were in contact with the soil. The symptoms and appearance of the disease were similar to those described for Dianthus.

LAMB'S QUARTERS, *Chenopodium album*

During the summer of 1913 several wilted *Chenopodium* plants were observed along the border of the old herbaceous grounds of the Station. On pulling up the wilted plants, it was found that *R. Solani* was the cause of the wilting. The fungus did not enter very deep into the tissues, but rather girdled the stem and formed a scurfy layer.

Duggar and Stewart[32] in 1901 reported the occurrence of Rhizoctonia on *Chenopodium album.*

Lavatera arborea variegata

During March, 1913, in the floricultural greenhouses, a number of seedlings in small seed pans, among which were several pans of Lavatera, began to damp off in a manner characteristic of *R. Solani.* Pure cultures of diseased seedlings yielded this fungus. Strands of the brown mycelium could be seen on the surface of the soil and extending up on the stems and leaves. This was noticed again in the spring of 1914.

LETTUCE, *Lactuca sativa*

Atkinson[4] in 1895 mentioned the damping-off of seedling lettuce, among a number of other plants, by a sterile mycelium which later proved to be Rhizoctonia.

Stone and Smith[128] found that *R. Solani* caused a rot of greenhouse lettuce, altho the disease was not common. The first appearance was on the lower leaves where they lay on the ground; a brown rot set in, which spread thru the leaf in a very characteristic manner. The green blade rapidly rotted away, leaving the midrib and stalk as sound as tho the blade had been carefully cut away or had been eaten by insects.

Duggar and Stewart[32] observed the damping-off of lettuce seedlings by Rhizoctonia for a number of years. They found that at or near the surface of the ground the tissues become water-soaked in appearance and unable longer to support the seedling, so that it falls to the ground, the fungus invading all parts. Within a day or two this fungus, under favorable conditions, wilted down and destroyed whole boxes of lettuce seedlings. Duggar and Stewart also observed several times what was apparently the same fungus causing a disease of mature lettuce plants. On the older leaves the leaf blades alone were affected, but the more delicate inner leaves succumbed entirely, blackening and decaying with the progress of the disease.

In 1903 Selby[104] reported the presence of a rosette disease of lettuce, which he described as follows: "The plants affected showed, usually not long after transplanting, but occasionally at other stages, a failure to send out central leaves freely. The leaf-bearing axis remained shortened, and the last leaves formed remained short, making a very striking contrast to the remainder of the plants in the bed and to the lower leaves of the same plant. (Frequently the plants overcome this tendency and make a fair amount of product with longer time.) Examination of the roots showed areas occupied by the hyphæ of Rhizoctonia." In 1906 Selby[106] treated at length the control of rosette in lettuce due to Rhizoctonia.

FIG. 14.—DAMPING-OFF OF LAVATERA SEEDLINGS BY *Rhizoctonia Solani* (Experiment 9)

In 1905 Rolfs[95] reported the presence of the perfect stage, *Corticium vagum* B. & C., on lettuce from Florida.

Lobelia erinus (Single Blue)

The lobelia plants in the floricultural greenhouses in 1914 were small and sessile, and covered the tops of the pots in which they were growing. In June a number of them began to die. On close examination, strands of *R. Solani* could be seen spreading thru the mass of plant material. The low-lying leaves afforded a good hiding place for sow bugs, and no doubt they helped in carrying the fungus from one pot to another. Attacks of Rhizoctonia on other varieties of lobelia have been observed in the greenhouses a number of times.

ONION, *Allium* sp.

A culture of Rhizoctonia isolated from onion seedlings was obtained from Cornell University by Mr. H. W. Anderson in 1911. Since that time the author has worked with this strain both in the laboratory and in the greenhouse. From its morphological and physiological behavior, it must be classed as distinct from the other strains.

Dr. I. C. Jagger states in a letter that he first isolated this form from onion on May 29, 1911, from seedlings growing on muck soil in New York. He found that the Rhizoctonia mycelium was always confined to the first, or seed, leaf and that damping-off ceased as soon as the second leaves had developed.

PANSY, *Viola tricolor*

During the fall of 1913 pansy plants were placed in a solid bed in the floricultural greenhouse, as a border for sweet peas. At that time some of the sweet-pea plants died, and eventually a culture of *R. Solani* was obtained from them. The following April several pansy plants in the vicinity of the spot where the sweet peas had died became diseased and later died. A culture showed the trouble to be due to Rhizoctonia. Later a large number of the plants in the row died. The fungus attacked the plant at the crown and caused a rapid rot. The prostrate branches, the petioles of the leaves, and even the leaves themselves were also rotted in a characteristic fashion. The strands of the mycelium could easily be seen ramifying between the rotting mass and the soil.

PLANTAIN, *Plantago aristata*

Diseased plants of plantain were found during June, 1914, in inoculated sections in one of the floricultural greenhouses. The mycelium of *R. Solani* was present around the bulbous base of the

plants, causing a crown rot. In one or two cases several leaves were completely rotted at the crown.

POINSETTIA, *Euphorbia pulcherrima*

About October 7, 1912, young poinsettia plants were taken from the cold house (50° to 60°C.) of the floricultural greenhouses and put in a box with a glass top. They were then placed near the cutting bench, in which a number of plants of various kinds were damping off. The poinsettia cuttings shortly afterwards began to die off rapidly. The characteristic lesions on the stems of the young plants and pure cultures of the diseased material indicated that this condition was due to *R. Solani*. The lesions, instead of being on one side and more or less localized, in almost every case formed a collar around the stem at the surface of the soil. The collar was about 2 to 3 millimeters wide, somewhat depressed, and of a dark color. Strands of the brown mycelium were visible spreading over the soil in the pots. This infection probably had its origin in the cutting bench.

POTATO, *Solanum tuberosum*

On the potato *R. Solani* exhibits a number of interesting characteristics, which vary with climatic conditions, age of the host, and part of the plant attacked.

The sclerotial stage of this fungus has been observed on practically every Illinois potato tuber examined by the writer. Moreover, in every shipment from other states which has been examined, the fungus has been found present. The tubers affected were dotted with brownish black sclerotia of various shapes and sizes (Fig. 15), but so far as could be determined, they were causing no direct injury. This type of Rhizoctonia disease of potato is the one most commonly found in the United States.

R. Solani also causes, under certain conditions, a russeting, or scab, a cracking of the tuber, the formation of pits at or near the lenticels, and a wet rot of the tuber. These types of injury have been observed by Rolfs[92-93] in Colorado, by Orton[73] in various states, and by Morse and Shapovalov[69] in Maine.

On the plant itself this fungus produces various types of diseases. In many cases young plants are completely cut off before they reach the surface of the ground. Older plants that are severely attacked just below the surface of the ground usually die off quickly. If they are only slightly attacked, the fungus produces small lesions on the stems, the plants take on a dwarfed and unhealthy appearance, and the tubers remain small, altho the plants usually live thru the summer. When the stem is girdled by the fungus so as to prevent translocation entirely, large tops are produced, aerial tubers are formed,

FIG. 15.—POTATO TUBER SHOWING THE SCLEROTIA OF *Rhizoctonia Solani*

and in some cases a curling of the leaves or rosetting results. When the main stem is attacked below the surface of the soil and the stolons are cut off, the condition known as "little potatoes" is produced; in such cases a cluster of small, short-stemmed tubers is formed above the wound. The production of aerial potatoes, rosette, and leaf curling also occurs when the stolons are attacked and the young tubers are cut off.

These abnormal developments of the potato are usually associated, and are secondary physiological effects due to disturbances of the nutrition of the plant. They occur most frequently on poorly drained land and especially on heavy soils.

Rolfs[92] attributed the potato failure of 1902-03 in Colorado to little potato. Selby[103] in Ohio, in his studies of the Rhizoctonia disease on potato, gave particular attention to rosette. In 1914 Morse and Shapovalov[69] concluded that the Rhizoctonia disease of potato is of a more serious nature than is generally considered. In one field which they had under observation for several seasons, they attributed the poor and uneven stands, unexpected low yields, early ripening, and death of the tops to Rhizoctonia. In most cases they confirmed the observations made by Rolfs. Recently investigators all over the country have been emphasizing the serious nature of the disease.

In January, 1915, material of *Rhizoctonia Crocorum* on potato tubers was received from Mr. F. D. Bailey of the Oregon Agricultural Experiment Station. On comparing it with *Rhizoctonia Solani*, it was found to be entirely different in all respects. However, this fungus is identical with the fungus on alfalfa reported by a number of observers (Webber, Heald, and Freeman) as *R. Crocorum*. Thus it appears that *R. Crocorum* is present in this country on alfalfa and on potato tubers.

Bailey[8] describes the Rhizoctonia disease of potato as follows:

"The surface was almost entirely covered with a dense, felt-like mat of a chocolate color when dry, violet-brown when moist. This mat was found to be composed of mycelium which had long narrow cells and a branching habit characteristic of Rhizoctonia. The greater part of this mycelial mat could be easily removed, and beneath this the surface of the tuber was covered with very small dark spots. These spots appeared to the unaided eye as minute eruptions of the skin. Under the microscope one can see the mycelial threads attached at these points, and a freehand section thru such a spot shows it to be a structure composed entirely of interwoven fungus threads forming a sclerotium. No evidence of differentiation or any type of spore formation within this body could be found on examination of many sections. The portion of the sclerotium near the surface is composed of cells that are very deeply colored, giving the black appearance. The outer surface of the sclerotium is seen to project above the surface, while the lower or underlying portion is embedded in the outer cortical layers of cells of the tuber. Furthermore, there is a strand of fungus tissue extending deeper than the sclerotium, which connects it with a layer of the same type of fungus tissue spreading between the cortex and parenchyma from the point where this strand reaches the parenchyma.

"Attempts to grow this fungus in culture failed. This has been the experience reported in attempts to grow *Rhizoctonia violacea* Tul."

RADISH, *Raphanus sativus*

Damping-off of radish seedlings by *R. Solani* has appeared several times in the floricultural greenhouses. During May, 1914, an attack of Rhizoctonia on mature radishes was observed in the writer's home garden. The first sign of the disease was the yellowing of the foliage, followed by the wilting of the leaves. On pulling up a plant, the crown was found to be rotted at the base of the leaves. The rot progressed slowly and killed only a few of the plants. After it had proceeded for some length, the radishes cracked farther down. This is very characteristic of the disease at this stage (Fig. 16).

In 1895 the damping-off of radish seedlings by a sterile fungus, which was later identified as Rhizoctonia, was first reported by Atkinson.[4] Duggar and Stewart[32] in 1901 noted a disease caused by Rhizoctonia of mature radishes forced in a greenhouse. The disease caused a soft rot of the crown or lesions in this region. The leaves were generally unaffected until a large part of the root had decayed. Plants in all stages of growth were affected and killed. Duggar and Stewart also found a Rhizoctonia in connection with the damping-off of radish seedlings in the greenhouse.

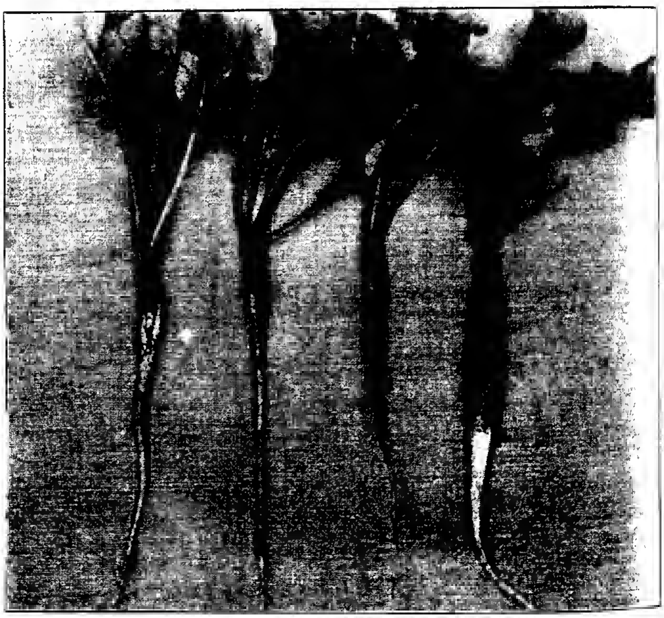

FIG. 16.—LATE STAGE OF ROOT ROT OF RADISHES CAUSED BY *Rhizoctonia Solani*

In 1904 Clinton[14] observed a damping-off and root rot of radish due to Rhizoctonia. Apparently the disease was not very serious. Stewart[125] in 1910 also reported a damping-off and root rot of radish due to Rhizoctonia. Infection took place first at the level of the soil, causing the leaves to have a wilted, drooping appearance. From this point the disease spread into the leaves and roots of the plant, soon causing death. On mature radishes, decayed spots of irregular shape were produced, and at an advanced stage the diseased portions of the plant were covered with a white, felted mycelium.

RHUBARB, *Rheum rhaponticum*

In 1901 Duggar and Stewart[32] reported a disease of rhubarb, on Long Island, which they had had under observation for several years. They described the disease as follows:

> "An unthrifty condition of the plants was noticed, followed by the rapid dying off of many of the leaves. The affected leaves became dry and shrunken in appearance and soon fell to the ground. Where a field was badly affected, the majority of hills showed the trouble to the extent of at least a leaf or two. In several instances from one-fourth to three-fourths of the leaves were already dead. An affected leaf breaks off readily just beneath the surface of the ground, and old dead leaves rotted off in this region. The general appearance reminded one strongly of the effect of Rhizoctonia upon beets. There was very little superficial mycelium visible to the unaided eye. Microscopic examination showed hyphæ of a Rhizoctonia both superficially and immediately under the surface where the leaves were rotting."

Clinton[14] has also reported a stem rot of rhubarb due to Rhizoctonia. He found the fungus at the base of leaf petioles, causing dark, sunken cankers.

SALVIA, *Salvia splendens*

The symptoms of the Rhizoctonia disease of salvia observed in the floricultural greenhouses were similar to those described for coleus. All varieties of the cuttings in the bench seemed to be equally susceptible. It has been shown that the serious damping-off of the salvia, alternanthera, and coleus was due to the fungus which was first brought in on the mature alternanthera plants from which cuttings were made. (See Alternanthera, page 310.)

Santolina chamæcyparissus

In 1914 a number of plants of *Santolina chamæcyparissus* growing in pots next to the *Centaurea gymnocarpa* in the floricultural greenhouses, were found to have a typical stem rot, due to *R. Solani*, very similar to the disease as described for that plant (see page 321). The fungus could be distinctly seen running thru the bushy branches.

Sedum sp.

A few plants of *Sedum anglicum*, together with several other species of *Sedum*, were found diseased, in July, 1913, in the herbaceous grounds. The progress of the disease was very slow; few plants were killed during the entire summer. For the most part, the fungus seemed to live saprophytically at the base of the plant. It was also found on healthy plants of this genus. About six species were planted in a row in the garden, and all were affected in much the same way.

SORREL, *Rumex acetosella*

In June, 1914, a number of sorrel plants were found diseased in an inoculated section in the greenhouse. The stems of the plants were covered with the brown strands of mycelium, and a few of the leaves were rotted off at the crown. Pure cultures of the diseased parts yielded *R. Solani* in every case.

SWEET PEA, *Lathyrus odoratus*

During July, 1912, when the young sweet peas in the field were about one-third to one-half grown, occasional vines showed evidence of disease by turning yellowish, wilting, and finally drying up entirely. An examination of the affected plants showed that they were more or less separated from their roots near the surface of the ground. Pure cultures of the diseased material yielded *R. Solani* in all cases.

In November, 1913, several diseased seedlings were brought in from the plant-breeding greenhouses. On close examination the stems showed the characteristic lesions caused by Rhizoctonia. The same trouble occurred in the floricultural greenhouses the past two seasons, but in no case was it severe.

During the winter of 1913, the writer was called to Chicago to look over a range of greenhouses devoted to the growing of sweet peas. Sweet-pea plants of all ages were seriously affected. Dead plants were scattered thru the whole house. Close examination of the diseased plants revealed the fact that Rhizoctonia was causing the trouble. Apparently it started in the seed pans and continued to work until the plants were ready to be discarded. The symptoms in each case were the same—yellowing of the foliage, followed by the wilting and drying up of the plants. Characteristic lesions, which finally cut the stems off at the surface of the soil, could always be found on the diseased plants. The root systems were much dwarfed.

In 1908 Clinton[16] observed in Connecticut a damping-off of sweet peas due to Rhizoctonia. Taubenhaus[130-131] in describing a Rhizoctonia rot of sweet pea at different stages, states that he found it quite destructive to the plants when they are in the seedling stage.

TOBACCO, *Nicotiana* sp.

In 1904 Clinton[14] noticed a seed-bed rot of tobacco, which he thought was due to Rhizoctonia. The same year Selby[105] observed a similar bed rot of tobacco in Ohio caused by Rhizoctonia. He stated that the specific characteristics of the fungus do not differ essentially from those of its forms on other plants, including potato.

Clinton,[15] in making another report on this disease, in 1906, stated that the injury to the plants was slight and was confined, as with the potato, to the underground parts.

Johnson[63] has carried on some extensive work on Rhizoctonia, with a view to controlling the damping-off of tobacco seedlings.

TOMATO, *Lycopersicum esculentum*

A damping-off disease of tomatoes caused by Rhizoctonia has been noted from a number of states; the symptoms of the disease are the same as have been described for a number of other plants, such as eggplant.

In connection with his work on the potato rosette resulting from Rhizoctonia, Selby[104] also mentioned a tomato rosette caused by the same fungus. He stated that the tips of diseased plants showed rather long internodes and dwarfed leaves, with somewhat curled-leaf aspects, while the roots had lesions and other similar features found in potato rosette.

Rolfs[95] in 1905 stated that he frequently found the Corticium stage on the tomato plant, but that apparently the plants do not suffer materially from its presence when planted on well-aerated land. He described it as follows:

"The fruiting stage of the fungus develops freely on the stem just above the surface of the ground, often extending up the stem for a distance of six inches. As a rule the fungus does not penetrate the tissue here, but simply covers the stem of the plant. The tomatoes which touch the ground are frequently more or less covered by a fruiting membrane of the fungus, which mars the appearance of the ripe fruit. So long as the tomatoes are green and the skin uninjured, the fruit remains sound; however, if the skin is ruptured, the fungus soon destroys it, producing a brown rot. This organism also frequently gains entrance to the fruit at the stem end."

Orton[72] described the rosette of tomato caused by *Corticium vagum* B. & C. as a disease of minor importance in tomato culture. He stated that "the fungus attacks the roots and base of the stem, forming dark cankers. The effect on the plant is to dwarf and curl the leaves and to restrict productiveness."

A fruit rot of the tomato has also been observed by Pool[86] and again by Wolf.[141] Pool described the symptoms of the fruit rot as follows:

"The specimen examined showed no rupture in the external skin visible to the naked eye. The diseased area was plainly distinguishable by the chocolate-

colored, slightly wrinkled epidermis. An examination of the underlying tissues revealed the same general color and numerous, somewhat darkened filaments penetrating the cells in all directions.''

Wollenweber[142] in 1913 described a species, *Rhizoctonia potomacensis* Wr., which causes a fruit rot of green tomatoes. He stated that this species differs from *Rhizoctonia Solani* in the character of its attacks, in that concentric, subepidermal mycelial zones are formed within the tomatoes.

VIOLET, *Viola odorata*

During the fall of 1913 a number of violet plants in the floricultural greenhouses were found to be diseased. A few had stem rot, while on others only the bases of the petioles were somewhat rotted. Where the pots were set close together and the plants overlapped, the brown strands of *R. Solani* could be plainly seen spreading out from one plant to another. However, in no case was the disease severe; it is probable that the fungus was living saprophytically on the lower leaves.

Duggar and Stewart[32] observed, in a greenhouse in New York, one case of destructive violet stem rot due to Rhizoctonia and a second case similar to the attack described above.

ADDITIONAL OBSERVATIONS

Beside the hosts that have been mentioned, observations have been made in the floricultural greenhouses of diseased seedlings and cuttings of a number of other plants, tho no work has been done further than to make a microscopic examination of the diseased material.

Below is a list of seedlings and cuttings found damping off in the spring and fall of 1914, with the percentage of loss resulting. In all cases Rhizoctonia proved to be the cause of the trouble.

Seedlings Damping off, April 6, 1914	Percentage of loss
Amaranthus caudatus	75
'' *salicifolius*	90
Bartonia aurea	90
Calendula Pongei	1–2
Celosia Huttoni, var. *Thompsonii magnifica*	75
Chrysanthemum hortorum	30–40
Dianthus chinensis	80
'' *Heddewigii*	30
'' *latifolius*	80
Godetia sp.	80
Gypsophila muralis	30
Kochia trichophylla	99
Lavatera arborea variegata	5
Linaria Maroccana	5
Linum grandiflorum rubrum	30
Lychnis coeli rosa	90
Portulaca oleracea	80
Schizanthus sp.	2–4

Seedlings Damping off, September 2, 1914	Percentage of loss
Aquilegia (6 species)	85
Campanula (8 species)	80
Cineraria (several species)	20
Dianthus plumarius	85
Erysimum pulchellum	2
Linaria Cymbalaria	2
Lythrum sp.	2
Matthiola incana (stocks)	2
Primula malacoides	2
" *obconica grandiflora*	2
Schizanthus (mixed)	2
Silene Schafta	100
Stachys lanata	2
Viola tricolor (3 varieties)	20

Cuttings Damping off, September 25, 1914	
Abutilon hybridum, var. *Savitzii*	100
Acalypha Wilkesiana, var. *bicolor*	100
" " " *tricolor*	100
" " " *marginata*	90
Ageratum mexicanum vars.	2
Alyssum odoratum (3 varieties)	100
Coleus (10 varieties)	2
Cuphea platycentra	2
Iresine (*Achyranthes*) (5 varieties)	95
Petunia (several varieties)	100
Piqueria trinervia (*Stevia*)	100
Santolina chamæcyparissus	2
Sedum spectabile	2
Telanthera (*Alternanthera*) (9 varieties)	2
Vinca major (several varieties)	2

TYPES OF SYMPTOMS

From a study of the symptoms caused by *Rhizoctonia Solani* on the various hosts, it is seen that, except for a few minor points, they are the same when appearing on the same type of host. The damping-off of seedlings and cuttings of various plants is identical, as is the rotting of a number of root crops. In most herbaceous plants a stem rot is produced, the symptoms of which are also identical on the various hosts. On very resistant plants lesions only are formed; these are apparently identical on the different hosts.

INOCULATION EXPERIMENTS

The main purpose of these inoculation experiments was to ascertain the degree of biologic specialization which may exist between the various cultural strains of Rhizoctonia, or between strains isolated from different hosts or of different geographical origin. With three thousand square feet of glass available in the floricultural greenhouses and with the assistance of the members of the floricultural division, it was possible to carry on cross-inoculation experiments involving about

3,000 cuttings, 2,000 plants, and 7,000 seedlings of various kinds. With these, comparisons were made of about forty-five strains of Rhizoctonia.

A large number of the strains used in these experiments were isolated by the writer from the various hosts found infected with Rhizoctonia in this vicinity. Other strains were obtained from various investigators thruout the country. Below is presented a list of the strains used and the source of each.

Alfalfa.—A Rhizoctonia culture from alfalfa was received from Dr. C. W. Edgerton, Baton Rouge, Louisiana, November 12, 1912. It was originally obtained by Dr. Edgerton in May, 1910, from alfalfa seedlings.

Alternanthera R.A.C.—A culture of Rhizoctonia was isolated from infected alternanthera cuttings found in the floricultural greenhouses in the fall of 1912.

Alternanthera R.A.F.—This strain was obtained at the same time as the preceding, from mature alternanthera plants in the field.

Amaranthus.—In August, 1913, Mr. W. H. Burkholder, of Cornell University, contributed several specimens of *Amaranthus retroflexus* infected with Rhizoctonia, from Irving, New York. The stems were covered with the immature, gray, felt-like mycelium of the Corticium stage. Scrapings of the hymenial layer of this stage yielded pure cultures of Rhizoctonia in every case.

Aster.—Early in 1913, Dr. F. A. Wolf sent to the writer a culture of Rhizoctonia which was the cause of the damping-off of China aster seedlings in flats in the greenhouse at Auburn, Alabama.

Bean.—A transfer of a culture of Rhizoctonia from bean was obtained in December, 1912, from Dr. J. T. Barrett, of this university. He in turn had received it from Dr. M. F. Barrus, of Cornell University, about 1910.

Beet.—A culture of Rhizoctonia was obtained from young seedlings of the garden beet found damping off in the vegetable-gardening greenhouses, July 10, 1913.

Begonia.—The strain from begonia was isolated by Mr. Anderson from cuttings found damping off in the floricultural greenhouses in the fall of 1911.

Carnation.—During the season of 1911-12, Mr. Anderson isolated Rhizoctonia from a number of carnation plants received from different sources, and during 1912-13 and 1913-14 the work was continued by the author, so that a comparison of a large number of cultures from diseased plants obtained from various localities was possible. The strains used are given below.

"Carnation R.K.": Isolated by Mr. Anderson from diseased carnation plants obtained at Urbana, Illinois, in October, 1911.

"Carnation R.O.": Culture isolated by Mr. Anderson in the fall of 1911, at Urbana.

"Carnation R.H.": Culture isolated from a diseased plant in the floricultural greenhouses in the fall of 1911 by Mr. Anderson.

"Carnation R.S.": Isolated from diseased plants received from Kankakee, Illinois, by Mr. Anderson, October 25, 1911.

"Carnation R. 2": Culture reisolated by Mr. Anderson from infected cuttings in sterilized soil in the spring of 1912.

"Carnation R.F.": Isolated from diseased carnation plants gathered in the field in the horticultural grounds, July 24, 1912.

"Carnation R.M.2": Isolated from a White Enchantress plant in one of the floricultural greenhouses during September, 1912.

"Carnation R. 107": Obtained from a plant in the floricultural greenhouses, September 7, 1912.

"Carnation R.F.2": Culture obtained from a diseased plant in the field during the summer of 1913.

"Carnation R. 121-5": A reisolation of Rhizoctonia was obtained on December 3, 1912, from a diseased plant in one of the inoculated sections of the greenhouse.

Carrot.—The strain of Rhizoctonia from carrot used in this work was obtained by Mr. Anderson from Cornell University in 1911. Nothing is known of the origin of the culture.

Cauliflower.—A culture of Rhizoctonia from cauliflower was obtained in 1912, from Dr. C. W. Edgerton, Baton Rouge, Louisiana. This culture was isolated from diseased cauliflower seedlings in the summer of 1912, so that it was a comparatively fresh culture when received here.

Chenopodium.—A culture was isolated during the summer of 1913 from mature plants of *Chenopodium album* growing along the border of the old herbaceous grounds back of the floricultural greenhouses.

Clover.—A culture of Rhizoctonia from red-clover roots was received from Mr. E. A. Arzberger, Wooster, Ohio, March 3, 1913. The fungus was isolated by him from red-clover roots in the greenhouse in December, 1912.

Coleus I.—This strain was obtained from coleus cuttings found damping off in the floricultural greenhouses, November, 1912.

Coleus II.—A culture was isolated from coleus seedlings damping off in seed pans, October, 1913, in the floricultural greenhouses.

Corn.—The strain from corn was obtained from Dr. J. J. Taubenhaus, Newark, Delaware, in 1912. He stated that the fungus had been isolated from corn seedlings that were damping off in the greenhouse.

Cotton.—Three cultures of Rhizoctonia from cotton received from two sources at different times, were used in these experiments. The strain "Cotton I" was received from Dr. C. W. Edgerton, Baton Rouge, Louisiana, November 12, 1912. This strain was cultured by him in September, 1911, from young diseased plants. The strain "Cotton II" was also received from Dr. Edgerton. This strain was cultured in February, 1912, from the same kind of material as the above. The third strain, "Cotton III," was received from Dr. F. C. Wolf, Auburn, Alabama, December 12, 1912. The fungus was isolated from seedling cotton plants growing in the station greenhouse at Auburn.

Dianthus.—Cultures of Rhizoctonia were isolated during July, 1913, from diseased plants of several species of *Dianthus* growing in the perennial garden. The strains cultured and used in the experiments were "D. barbatus N. P.," "D. barbatus S. M.," "D. plumarius," and "D. sequeri."

Eggplant.—Two strains of Rhizoctonia were isolated from eggplant: one, causing a fruit rot, was cultured August, 1912; the other was isolated from seedlings damping off in flats in the vegetable-gardening greenhouse, July, 1913.

Gypsophila repens.—A culture of Rhizoctonia was isolated during July, 1913, from diseased *Gypsophila* plants in the perennial garden.

Lavatera.—A culture was isolated in 1913 from seedlings of lavatera found damping off in pans in the floricultural greenhouses.

Lettuce.—The strain from lettuce was obtained by Mr. Anderson in 1911, from Cornell University.

Poinsettia.—Cultures were obtained from damping-off poinsettia cuttings found in the floricultural greenhouses, October, 1912.

Potato.—Several strains from potato were used in these experiments. Two of these strains were obtained from scrapings of the hymenial layer of the Corticium stage.

"Potato R.P.C."—A culture of this strain was isolated from fresh potato stems received from Dr. I. C. Jagger, Williamson, New York, September 2, 1912. This material contained the perfect stage, *Corticium vagum* B. & C. Pure cultures of Rhizoctonia were obtained from scrapings of the hymenial layer.

"Potato R.P.I."—In response to a letter from Mr. Anderson, Dr. Geo. H. Pethybridge, Clifden county, Galway, Ireland, sent a small box of potato stems containing the perfect stage, *Corticium vagum* B. & C. This material was sent by post, July 18, 1912, and received August 5. A pure culture of Rhizoctonia was obtained from scrapings of the gray mycelium of the Corticium stage.

"Potato R.P.O."—A culture from potato was obtained by Mr. Anderson from Cornell University. The strain was old and grew very poorly on agar.

"Potato R. Sol."—This strain, like the preceding one, was obtained by Mr. Anderson from Cornell University. It also grew very poorly on agar.

Radish.—A culture of Rhizoctonia from radish was obtained from Cornell University, by Mr. Anderson, in 1911. This form was very old and probably had been in culture several years. It was lost in April, 1913.

Salvia.—The strain from salvia was isolated from cuttings which were found in the same bench with a number of other cuttings damping off, October, 1912.

Sedum.—A culture of Rhizoctonia from sedum was isolated from diseased plants found in the herbaceous grounds in July, 1913.

Sugar Cane.—A culture of Rhizoctonia isolated from sugar cane was received from Dr. C. W. Edgerton, November 12, 1912. This culture was obtained in April, 1912. It was fresh and virulent.

Thistle.—A culture of Rhizoctonia from thistle was obtained by Mr. Anderson from Cornell University in 1911.

The method of infecting the cuttings, seedlings, and young plants grown in flats and benches, was as follows: Small flats, varying in size with the experiment, were first soaked in a strong solution of formalin for several minutes and then allowed to dry. Steam-sterilized sand or soil and a soil culture of Rhizoctonia were then mixed together in the flats and watered. After being tamped down, the flats were left standing for two days in order to allow the fungus to spread thru the soil. Later, the cuttings, seeds, or plants were put in the flats and placed in a chamber in the greenhouse where the moisture could be controlled. Bottom heat was furnished. The temperature varied somewhat during the experiment, but the average was about 60° F. When only individual plants in pots or in benches were to be infected, a portion of a culture of Rhizoctonia two weeks old on green-bean plugs was placed in contact with the stem of each plant about one-half inch below the surface of the soil, where it would be protected from light and desiccation.

FIG. 17.—SOIL CULTURE OF RHIZOCTONIA

In obtaining soil cultures of Rhizoctonia in large quantities, Mason jars with modified covers were found to be very suitable containers. A hole about one inch in diameter was cut in the

center of the cover, and a small tin tube about two inches long was inserted and soldered in. This hole was plugged with cotton. (See Fig. 17.) A mixture of 200 grams of dry sand and 10 grams of corn meal was then placed in the jars and moistened with distilled water until the sand was wet thru. The jars and their contents were then sterilized for one hour at twenty pounds pressure in an autoclave, after which the sand was inoculated with a small piece of infected green-bean plug upon which Rhizoctonia was growing luxuriantly. In about a month the soil was permeated with the mycelium, and numerous brown sclerotia of various sizes were formed. When smaller amounts of infected soil were needed, a 250-cc. flask was used.

No plant was listed as diseased until a pure culture of Rhizoctonia had been isolated from it. Pure cultures were easily obtained by soaking small pieces of diseased parts in 1-1000 mercuric chlorid for two minutes and then placing them on green-bean agar. Rhizoctonia developed rapidly, and in twenty-four to forty-eight hours would spread out from the diseased parts.

EXPERIMENTS 1 AND 1A: INOCULATION OF CARNATION CUTTINGS WITH VARIOUS STRAINS OF RHIZOCTONIA

Rhizoctonia is the fungus most commonly found causing a damping-off of carnation cuttings in the greenhouse. To determine whether any of the strains from sources other than carnation are able to attack carnation cuttings with the same ease as those from carnation, the following experiment was carried out. Nine hundred carnation cuttings and 28 strains were used in 1913, and 1,725 cuttings and 34 strains in 1914.

Sterilized flats (7x10 inches) were filled with sterilized sand; a 250-cc. soil culture of Rhizoctonia was then added to each and the sand tamped down and watered. One flat was left uninoculated to serve as a check. After two days, thirty carnation cuttings (White Enchantress) were planted in each flat, January 2-3, 1913. The flats were then placed in the moist chamber.

The inoculated cuttings began to die in about three weeks (January 25), and continued dying until the healthy cuttings had rooted, when the experiment was discontinued (February 11) (Fig. 18). The results are given in Table 3.

In most cases the cuttings inoculated with the various strains from carnation showed a soft, wet, progressive rot at the callus, which extended in many cases to the surface of the sand. This rot was very characteristic of the attacks of the carnation strains (Fig. 12). At other times the fungus attacked the cuttings just below the surface of the soil, forming lesions of various sizes at the leaf bases. Mycelium and sclerotia were also formed along the stems and in practically all cases between the leaves just above the soil.

TABLE 3.—SUSCEPTIBILITY OF CARNATION CUTTINGS TO VARIOUS STRAINS OF RHIZOCTONIA: EXPERIMENTS 1 AND 1A

Strain	Date of isolation	Number of plants					
		Experiment 1: 1913			Experiment 1a: 1914		
		Healthy	Wilted	Dead	Healthy	Wilted	Dead
Alfalfa	1910	10	14	6	..	..	..
Alternanthera R.A.C.	1912	2	2	26	2	0	46
″ R.A.F.	1912	3	1	26	0	0	48
Amaranthus	1913	..	..	..	0	0	48
Aster	1913	..	..	..	33	5	10
Bean	*	8	7	15	0	0	48
Beet	1913	..	..	..	0	0	48
Begonia	1911	0	0	30	..	..	..
Carnation R.K.	1911	3	1	26	..	..	..
″ R.O.	1911	19	11	0	..	..	..
″ R.H.	1911	6	0	24	0	0	48
″ R.S.	1911	5	2	23	..	..	..
″ R.2	1912	0	2	28	..	..	..
″ R.F.	1912	0	2	28	3	0	45
″ R.M.2	1912	1	3	26	22	9	17
″ R.107	1912	2	3	25	4	0	44
″ R.F.2	1913	..	..	..	0	0	48
Carrot	*	4	18	8	32	2	14
Cauliflower	1912	0	0	30	0	0	48
Chenopodium	1913	..	..	..	33	0	15
Clover	1912	..	..	..	12	0	36
Coleus I	1912	0	0	30	0	0	48
″ II	1913	..	..	..	0	0	48
Corn	1912	..	..	..	31	3	14
Cotton I	1911	0	0	30	18	0	30
″ II	1912	0	0	30	4	2	42
″ III	1912	..	..	..	14	0	34
Dianthus barbatus S.M.	1913	..	..	..	0	1	47
″ ″ N.P.	1913	..	..	..	0	0	48
″ plumarius	1913	..	..	..	0	0	48
″ sequeri	1913	..	..	..	0	0	48
Eggplant I	1912	14	6	10	3	0	45
″ II	1913	..	..	..	8	0	40
Lavatera	1913	..	..	..	0	1	47
Lettuce	*	18	12	0	34	0	14
Poinsettia	1912	7	1	22	23	0	25
Potato R.P.C.	1912	4	2	24	..	..	..
″ R.P.I.	1912	9	4	17	..	..	..
″ R.P.O.	*	9	7	14	..	..	..
″ R.Sol.	*	10	6	14	..	..	..
Salvia	1912	16	11	3	24	2	22
Sedum	1913	..	..	..	0	0	48
Sugar cane	1912	3	3	24	34	3	11
Thistle	*	8	18	4	24	2	22
Check	....	4	26	0	..	..	..
″	....	..	..	..	46	2	0
″	....	..	..	..	47	1	0

*This strain had been in culture for a number of years; the exact year of isolation is not known.

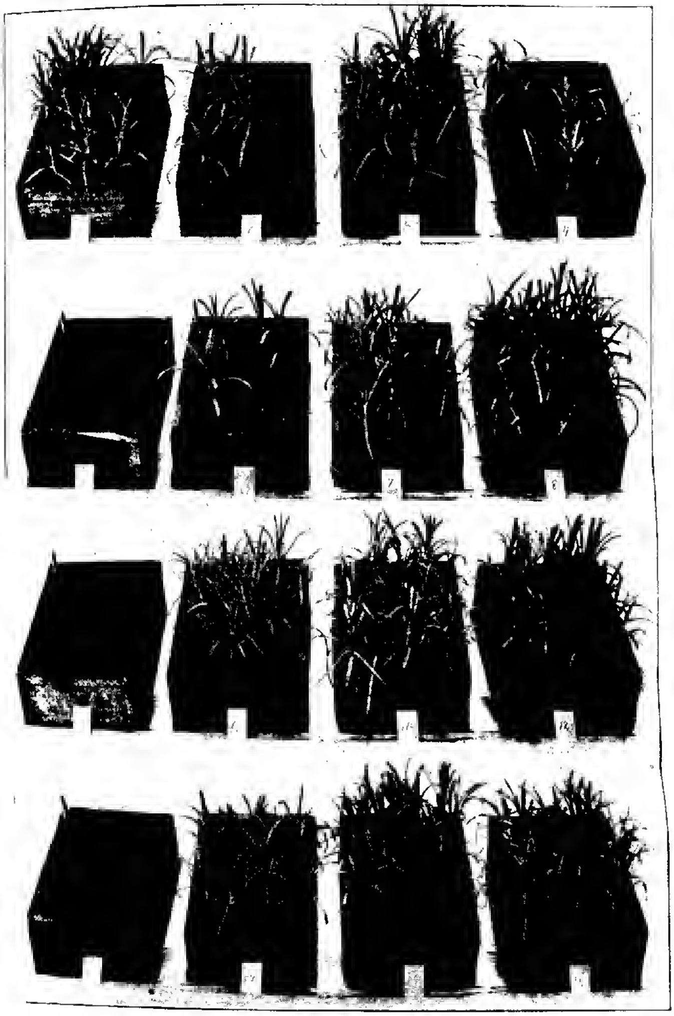

FIG. 18.—EXPERIMENTS 1 AND 1A: CARNATION CUTTINGS INFECTED WITH RHIZOCTONIA STRAINS (1) CARNATION R.K.; (2) CARNATION R. 107; (3) CARNATION R.O.; (4) CARNATION R.F. (5) BEGONIA; (6) COLEUS; (7) POINSETTIA; (8) SALVIA; (9) CAULIFLOWER; (10) THISTLE; (11) LETTUCE; (12) POTATO R.P.C.; (13) COTTON; (14) BEAN; (15) POTATO R.P.O.; (16) CARROT

The percentage of infection was about the same with all the carnation strains except "Carnation R.O.," which appeared to have lost practically all power of attacking cuttings. This was one of the first strains isolated from carnation. Thus the age of the strain seemed to play an important rôle in its virulence, and for this reason the date of the original isolation of each strain is included in the table.

The strains from alternanthera, coleus, salvia, and poinsettia, all of which were isolated from diseased plants in the same cutting bench, produced in some cases a soft wet rot of the carnation cuttings similar to that caused by the carnation strains. In the majority of cases, however, these strains attacked the cuttings at the callus, forming large brown sclerotia which covered the whole callus and so prevented the formation of roots. Brown strands of the mycelium and sclerotia were formed on all parts of the cuttings underground and also between the leaves. Occasionally, small lesions appeared at the leaf bases which were slightly under the surface of the sand.

The two strains from alternanthera and the one from poinsettia killed about the same number of cuttings as the strains from carnation, while the one from coleus caused 100-percent infection and rotted the cuttings off faster than the strains from carnation. The percentage of infection with the strain from salvia was very low.

The strain from begonia produced a soft rot somewhat different from that produced by the carnation strains. It appeared on the stem at the surface of the soil and sometimes at the callus. The fungus formed a dense mass of mycelium which completely covered the sand beneath. Here again the virulence was greater than with the carnation strains, all the cuttings being killed and in a much shorter time.

The strains from eggplant, lettuce, and thistle for the most part formed many sclerotia on the stems and in between the leaves of the cuttings, with only an occasional sclerotium at the callus. Small lesions were found to be abundant at the leaf bases and on the stems. These strains were very weak, especially those from lettuce and thistle, which had been in culture for a number of years.

The cuttings infected with strains from cotton, cauliflower, and sugar cane rotted off at the surface of the soil; the rot started as a lesion at this point and progressed very rapidly until the cutting was killed. Smaller lesions were produced on the stem underground. Sclerotia and the brown strands of the fungus could be found in abundance on the parts below the soil. The strains from cotton and cauliflower were very virulent; all the cuttings inoculated with them were killed one week before the cuttings inoculated with a soil culture of the carnation strains began to die off.

The potato strains, as a rule, produced a large number of sclerotia and a dark brown mycelium below the soil and on the leaves. The percentage of infection was fairly high and uniform altho the average was below that of the carnation strains.

The strains from alfalfa, bean, and carrot produced symptoms similar to those from potato. A large number of the cuttings placed in the uninoculated sand wilted, but none became diseased.

During the spring of 1914, beginning on March 7 and ending on April 7, the experiment was repeated, the only difference being that a number of additional strains were used and flats containing forty-eight cuttings instead of thirty. As will be seen in Table 3, the results were confirmatory. The marked increase in the virulence of the lettuce strain may have been due in part to the influence of temperature both on the strain and on the cuttings.

EXPERIMENTS 2 AND 2A; INOCULATION OF YOUNG CARNATION PLANTS WITH VARIOUS STRAINS OF RHIZOCTONIA

That the majority of strains can attack carnation cuttings was shown in Experiments 1 and 1a, where it appeared that the virulence of the strain did not depend on the host from which it was originally isolated, but in some cases did depend on the length of time since the culture was isolated. To determine whether rooted plants were as susceptible to these various strains of Rhizoctonia as were cuttings, further experiments were carried out: Experiment 2 in 1913, involving about 400 young plants and 24 strains; and Experiment 2a in 1914, in which about the same number of plants but only 13 strains were used.

Carnation cuttings (White Enchantress) which had been placed in sterilized sand December 12, 1912, were planted February 12, 1913, in sterilized flats (9x12 inches) containing sterilized soil, fifteen plants in each flat. Plants failing to strike root were pulled out, leaving an unequal number in the various flats. The flats were inoculated on March 23 with 250-cc. soil cultures of Rhizoctonia, each flat with a different strain. They were then placed in a case in the greenhouse and left during April and May.

Usually the carnation strains, as in the case of the cuttings (Experiments 1 and 1a), produced a soft, wet rot at the surface of the soil or just below. On other plants they caused small lesions of various sizes along the stems, killing the plants slowly. Sclerotia and brown strands of mycelium were as a rule present on plants which showed lesions and on others less badly diseased.

Only an occasional plant in the flats infected with other strains than carnation developed a soft, wet rot. In the majority of cases where infection took place the strains produced lesions of various sizes on the stems at the surface of the soil or just below, slowly killing the plants (Fig. 13). As a rule, sclerotia and mycelium were also present on the stems of the infected plants. The plants in the check flat remained healthy.

The resistance of the rooted carnation plants to the fungus, as shown in Table 4, was much more marked than with the cuttings. In the few exceptions the fungus appeared able to infect the plants almost as readily as it had the cuttings.

In 1914 this experiment was essentially repeated. Thirty young carnation plants (Rosette) were placed in each of a number of flats (12x18 inches). On April 26, after the plants were rooted, some of the old infected sand from the inoculated flats used in Experiment 1a was mixed with the soil in which the plants were growing. The experiment was continued until June 1. The results, which are presented in Table 4, were similar to those of Experiment 2. As in that experiment, the plants in the check flat remained healthy, with the exception of two that wilted and died from attacks of a Fusarium.

TABLE 4.—SUSCEPTIBILITY OF YOUNG ROOTED CARNATION PLANTS TO VARIOUS STRAINS OF RHIZOCTONIA: EXPERIMENTS 2 AND 2A

Strain	Number of plants					
	Experiment 2: 1913			Experiment 2a: 1914		
	Total	Healthy	Dead	Total	Healthy	Dead
Alternanthera R.A.C.	15	12	3	..	..	..
” R.A.F.	15	5	10	30	18	12
Amaranthus	..	..	..	30	25	5
Beet	..	..	..	30	20	10
Begonia	15	14	1	..	..	..
Carnation R.K.	14	2	12	..	..	..
” R.H.	..	..	..	30	15	15
” R.S.	14	1	13	..	..	..
” R.2.	13	6	7	..	..	..
” R.F.	14	2	12	..	..	..
” R.F.	15	0	15	30	15	15
” R.M.2.	14	2	12	..	..	..
” R.107	15	4	11	..	..	..
” R.F.2.	..	..	..	30	10	20
Carrot	15	13	2	..	..	..
Cauliflower	15	9	6	30	22	8
Coleus 1	15	9	6	30	23	7
Cotton 1	15	2	13	30	13	17
” 11	15	8	7	..	..	..
” 111	14	10	4	..	..	..
Dianthus barbatus N.P.	..	..	..	30	12	18
Eggplant 1	15	6	9	30	24	6
Lavatera	..	..	..	30	19	11
Lettuce	15	13	2	..	..	..
Potato R.P.C.	15	15	0	..	..	..
” R.P.I.	14	7	7	..	..	..
” R.P.O.	14	8	6	..	..	..
Salvia	15	10	5	..	..	..
Sedum	..	..	..	30	24	6
Sugar cane	15	13	2	..	..	..
Thistle	14	12	2	..	..	..
Check	15	15	0	..	..	..
”	..	..	..	30	28	2*

*Killed by Fusarium.

EXPERIMENT 3: INOCULATION OF OLD CARNATION PLANTS IN POTS WITH VARIOUS STRAINS OF RHIZOCTONIA

The resistance of young rooted carnation plants to the various strains of Rhizoctonia other than those from carnation was very marked in Experiments 2 and 2a. To determine whether or not old carnation plants were even more resistant, the following experiment was carried out, involving 90 plants and 18 strains.

Carnation plants (White Enchantress and White Perfection) were brought in from the field and planted in pots, which were then placed in the bench. The plants were grown under the best possible cultural conditions and on November 27, 1912, when they had become firmly established, they were inoculated. Five plants of the same size were used for each test, one being left as a check. The other four were inoculated by placing a bit of infected green-bean plug near the stem about one-half inch below the surface of the ground. The stems of two plants of each test were slightly wounded before the plugs were placed by them. Observations were discontinued on March 27, four months later. The results are presented in Table 5.

Only two plants inoculated by contact died during the course of the experiment, and both were killed by carnation strains. However, where the stem was slit, the various strains were in most cases able to infect and kill the plant. The check plants remained healthy during the experiment.

TABLE 5.—SUSCEPTIBILITY OF OLD CARNATION PLANTS (IN POTS) TO VARIOUS STRAINS OF RHIZOCTONIA: EXPERIMENT 3

Strain	Plants inoculated by				Check plants	
	Contact		Slit			
	Healthy	Diseased	Healthy	Diseased	Healthy	Diseased
Alternanthera R.A.F.	2	0	1	1	1	0
Carnation R.K.	2	0	0	2	1	0
,, R.O.	2	0	0	2	1	0
,, R.H.	2	0	0	2	1	0
,, R.S.	1	1	0	2	1	0
,, R.2	1	1	0	2	1	0
,, R.F.	2	0	0	2	1	0
,, R.M.2	2	0	1	1	1	0
,, R.107	2	0	0	2	1	0
Carrot	2	0	2	0	1	0
Cotton II	2	0	1	1	1	0
Eggplant I	2	0	0	2	1	0
Lettuce	2	0	0	2	1	0
Poinsettia	2	0	0	2	1	0
Potato R. Sol.	2	0	0	2	1	0
,, R.P.O.	2	0	1	1	1	0
,, R.P.I.	2	0	0	2	1	0
Thistle	2	0	0	2	1	0

EXPERIMENT 4: INOCULATION OF YOUNG CARNATION PLANTS WITH ISOLATED AND WITH REISOLATED STRAINS OF RHIZOCTONIA

The object of Experiment 4 was to compare the virulence of various strains of Rhizoctonia when they were inoculated on carnation plants for the first time, and after they had been inoculated on carnation and reisolated. Fifteen strains, taken at random, and about 300 plants were used.

On December 12, 1912, a number of carnation cuttings were made and placed in sterilized sand. They were allowed to remain in the sand until well rooted. On March 22, when the plants were from four to six inches high and breaking nicely, they were placed in three-inch pots in sterilized soil. They were then inoculated by placing a bit of bean pod infected with Rhizoctonia near the stem just below the surface of the soil. Table 6 gives the results obtained.

With seven strains the virulence of the reisolated fungus was slightly greater than that of the original isolation. With two it was slightly less.

TABLE 6.—COMPARATIVE VIRULENCE OF ISOLATED AND REISOLATED STRAINS OF RHIZOCTONIA WHEN INOCULATED ON YOUNG CARNATION PLANTS (IN POTS): EXPERIMENT 4

Strain	Original isolation		Reisolation	
	Healthy	Diseased	Healthy	Diseased
Bean	9	1	9	1
Carnation R.K.	6	4	1	9
,, R.K.	..	..	1	9
,, R.H.	5	5	2	8
,, R.S.	6	4	5	5
,, R.2	10	0	7	3
,, R.F.	7	3	4	6
,, R.F.	..	..	3	7
,, R.M.2	4	6	7	3
,, R.107	4	6	5	5
Cauliflower	10	0	10	0
Cotton I	9	1	7	3
,, II	10	0	10	0
Potato R.P.I.	9	1	8	2
Sugar cane	10	0	9	1
Check	10	0	..	..
,,	10	0	..	..
,,	10	0	..	..

EXPERIMENT 5: INOCULATION OF OLD CARNATION PLANTS IN THE BENCH WITH VARIOUS STRAINS OF RHIZOCTONIA

Experiment 5 was similar to the preceding experiment except that the carnation plants used were older and were grown in the bench instead of in pots, and that inoculations were made with only eight strains of Rhizoctonia, chosen at random.

On September 1, 1913, the soil in two five-foot sections in the green-ouse was sterilized, and twenty carnation plants from the field were laced in each section, four plants in a row. Four rows in each sec-ion were each inoculated with a different strain of Rhizoctonia, by neans of pieces of infected bean plugs. The middle row in each sec-ion was left as a check.

The plants began to die off at the end of three weeks and con-inued dying until the close of the experiment, October 31. They all lied in a manner characteristic of stem rot. All the strains used roved to be virulent except the one from beet (see Table 7). The heck plants remained healthy thruout the experiment.

ABLE 7.—SUSCEPTIBILITY OF OLD CARNATION PLANTS (IN THE BENCH) TO VARIOUS STRAINS OF RHIZOCTONIA: EXPERIMENT 5

Strain	Healthy	Diseased
eet	3	1
'arnation R.107	0	4
'auliflower	1	3
'otton 11	0	4
ianthus barbatus S.M.	1	3
" plumarius	0	4
ggplant 1	1	3
'otato R. Sol	1	3
heck	4	0
"	4	0

The high mortality of the strains in this experiment was due, to a arge extent, to the date of inoculation. The plants in the preceding xperiments were inoculated either late in the fall or in the early pring, when the temperature in the greenhouse was low and normal nd not influenced by outside conditions. The temperature in the ouse during September and October, when these plants were inocu-ated, is very high; hence the virulence of the fungus was much greater. The effects of inoculating plants at various times of the year are learly brought out in the next experiment.

EXPERIMENT 6: INOCULATION OF CARNATION PLANTS WITH RHIZOCTONIA AT DIFFERENT TEMPERATURES

During the season 1913-14 a number of sections containing carna-tions were reserved in the greenhouse, and at different times of the year the plants were inoculated with Rhizoctonia from carnation. This experiment was for the purpose of ascertaining the relative virulence of Rhizoctonia when inoculated on carnation plants at dif-ferent temperatures.

Each section contained twenty plants, sixteen of which were in-oculated by placing infected bean plugs at the base of the stem. The remaining four plants served as checks.

TABLE 8.—RELATIVE VIRULENCE OF RHIZOCTONIA INOCULATED ON CARNATION PLANTS AT DIFFERENT TEMPERATURES: EXPERIMENT 6

Section	Date of inoculation	Experiment discontinued	Inoculated plants		Check plants	
			Healthy	Diseased	Healthy	Diseased
143	Sept. 1, 1913	Oct. 1, 1913	1	15	4	0
140	Oct. 1, 1913	Nov. 1, 1913	3	13	4	0
139	Nov. 1, 1913	Jan. 1, 1914	10	6	4	0
138	Dec. 1, 1913	Feb. 1, 1914	8	8	4	0
137	Jan. 1, 1914	Mar. 1, 1914	14	2	4	0
134	Feb. 1, 1914	Apr. 1, 1914	3	13[a]	4	0
133	Mar. 1, 1914	May 1, 1914	12	4	4	0
132	Apr. 1, 1914	June 1, 1914	9	7	4	0
131	May 1, 1914	July 1, 1914	0	16	4	0
130	June 1, 1914	July 1, 1914	2	14	4	0
128	July 1, 1914	July 23, 1914	6	10	4	0

[a]Ten plants found infected April 1; only three plants died during the months of February and March.

As can be seen from Table 8, the death rate of the plants inoculated on September 1 and October 1 was almost 100 percent. This rate diminished very markedly when the plants were inoculated later in the season, increasing with the plants inoculated during the spring months until with those inoculated on May 1, it had again reached a high percentage. This condition prevailed during the summer months, showing very noticeably the influence of temperature on mortality.

EXPERIMENT 7: INOCULATION OF VARIOUS HOSTS (SEEDLINGS) OTHER THAN CARNATION WITH VARIOUS STRAINS OF RHIZOCTONIA

In the preceding experiments all the work was carried on with carnation plants of different ages. It was found that under certain conditions all the strains used could attack these plants, but that the resistance was somewhat increased when the plants were rooted. To determine whether the same results could be obtained with other plants, a number of further experiments were made.

Small flats (8x10 inches) were disinfected and filled with a mixture of sterilized sand and soil suitable for germinating seed. In each flat a 250-cc. soil culture of one of the various strains used was thoroly mixed with the soil, and the whole allowed to stand for several days. The seeds, after a short soaking in formalin (1–150), were sown in the flats, thirty-one in all, care being taken not to plant them too closely. Nine different kinds of seedlings and 13 strains were used in the experiment. The results obtained are given in Table 9.

In the first group of the various hosts, clover proved to be more resistant than alfalfa, while the injury to corn roots was negligible. Of the different strains, the one from clover proved the most virulent, while the one from corn was the weakest (Fig. 19).

TABLE 9.—SUSCEPTIBILITY OF VARIOUS PLANTS (SEEDLINGS) OTHER THAN CARNATION TO VARIOUS STRAINS OF RHIZOCTONIA: EXPERIMENT 7

Group 1

Strain	On clover	On alfalfa	On corn
Clover	*150 seeds* Most of seedlings killed at germination; 6 came up; 5 infected below surface of ground, showing lesions; 1 healthy	*150 seeds* All seeds attacked by fungus at germination. Rhizoctonia present in seeds	*30 seeds* Plants 4–6 inches high. Seed in all cases showed the presence of Rhizoctonia, but whether it would kill the whole plant is a question. However, fungus is able to live in the roots of the corn. Cultures of Rhizoctonia were obtained from the seeds
Alfalfa	About 15 percent damped off in typical manner. Lesions at surface of ground	80 percent damped off. Others in various stages of infection. 5 percent healthy	
Carnation R. 107	Only few plants infected. First leaves of a large number dead from effects of fungus	70 percent damped off. Condition similar to that of plants inoculated with alfalfa strain	
Corn	2 percent damped off. Rhizoctonia present on the roots of living plants, but did not seem virulent	8 percent damped off. Remaining plants healthy	

Group 2

Strain	On lettuce	On eggplant	On cabbage
Lettuce	*150 seeds* 90 percent damped off. Lesions on stem at surface of ground. Leaves also attacked, causing a rot	*150 seeds* 2 percent damped off. Lesions at surface of ground. Typical	*150 seeds*
Eggplant I	75 percent damped off. Lesions typical, like lettuce	3–4 percent damped off. Typical	
Thistle	60 percent damped off. Lesions typical, like those on plants inoculated with eggplant strain. Action of fungus slower but virulent	5 percent damped off. Small circular lesions present. Typical	
Carnation R.F.	60 percent damped off. Like thistle; slower in effect, but still virulent	All healthy	40 percent infected. Lesions in form of a collar around stem at surface of ground
Cauliflower	3 percent damped off. Typical lesions		Only 3 plants healthy. Seedlings attacked at germination

TABLE 9.—*Concluded*

Group 3			
Strain	On radish	On turnip	On beet
Radish	*150 seeds* 1 percent infected at base of stems. Several completely rotted	*150 seeds* Seedlings attacked at germination. Only 2 healthy plants	*100 seeds*
Potato R.P.C. ...	15 percent infected at base of stems where root begins. Small wounds like potato scab due to Rhizoctonia		50 percent damped off. Some rotted off at the ground
Carrot	Seedlings attacked at germination. Only 3 healthy plants	50 percent infected. All showed collar rot. Some rotted off	
Carnation R.F. ..	50 percent infected. Lesions at base of stems. Few rotted off		98 percent damped off. Showed collar rot. Typical

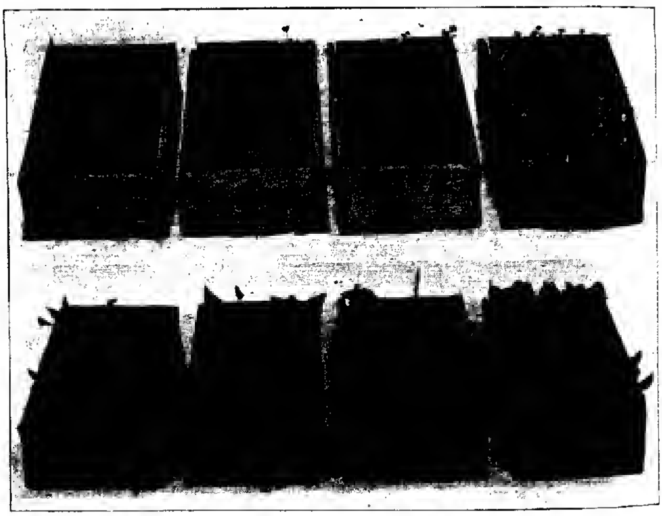

FIG. 19.—EXPERIMENT 7: UPPER ROW: ALFALFA SEEDLINGS INFECTED WITH RHIZOCTONIA STRAINS (1) CLOVER; (2) ALFALFA; (3) CARNATION R. 107; (4) CORN. LOWER ROW: LETTUCE SEEDLINGS INFECTED WITH RHIZOCTONIA STRAINS (1) LETTUCE; (2) EGGPLANT I; (3) THISTLE; (4) CARNATION R.F.

Of the seedlings in the second group, lettuce and cabbage were quite susceptible; eggplant seedlings were very resistant. The strain from cauliflower, altho it caused only a slight damping-off of lettuce

seedlings, produced practically 100-percent infection in the case of cabbage seedlings (Fig. 19).

In the third group, beet, radish, and turnip seedlings proved very susceptible to damping-off of Rhizoctonia. It is rather interesting to observe that while the strain from radish was able to cause only 1-percent infection of radish seedlings, it caused almost 100-percent infection of turnip seedlings.

Taking the experiment as a whole, it is seen that a great variation exists in susceptibility of seedlings and in virulence of strains. It is clear that under certain conditions all the strains can attack a given host with about the same virulence.

EXPERIMENT 8: INOCULATION OF VARIOUS HOSTS (OLD) OTHER THAN CARNATION WITH VARIOUS STRAINS OF RHIZOCTONIA

In Experiment 8 the preceding experiment was carried one step farther, older plants being used rather than seedlings. A number of plants were taken from flats while small and transplanted to four-inch pots, where they were allowed to grow for about two months. The soil in these pots was not sterilized. Each plant, with the exception of the check plants, was inoculated by placing an infected bean plug in contact with it just below the surface of the soil. Four kinds of plants, 50 of each, and 12 strains were employed. The observations from this experiment are recorded in Table 10.

In Group 1, the tomato plants proved resistant to the attacks of the various strains, with the exception of the one from carnation, which produced a slight infection on two plants. In the case of the cabbage plants, the strains from cotton and from cauliflower exhibited a marked specialization, producing 50- and 90-percent infection, respectively, on these plants, while on tomato plants they produced no infection whatever. Cabbage was the only host in the experiment susceptible to all the strains with which it was inoculated.

The carnation strains in Groups 2 and 3 also proved more virulent than the other strains, producing 50-percent infection on lettuce and 100-percent infection on beet (Fig. 9). Of the other strains, eggplant alone was able to attack the plants, producing a slight infection on two lettuce plants.

EXPERIMENT 9: INOCULATION OF VARIOUS HOSTS (CUTTINGS, SEEDLINGS, AND LARGER PLANTS) WITH VARIOUS STRAINS OF RHIZOCTONIA

The kinds of plants used in the foregoing experiments were somewhat limited. Increased facilities being at hand in the spring of 1914, a more extensive series of inoculations was made with cuttings, seedlings, and larger plants of various kinds. In all, about 350 cuttings, 3,000 seedlings, and 300 larger plants were inoculated. Thirty-two strains of Rhizoctonia were used.

TABLE 10.—SUSCEPTIBILITY OF VARIOUS HOSTS (PLANTS) OTHER THAN CARNATION TO VARIOUS STRAINS OF RHIZOCTONIA: EXPERIMENT 8

Group 1			Group 2		Group 3	
Strain	On tomato	On cabbage	Strain	On lettuce	Strain	On beet
Alfalfa	10 plants healthy	8 plants healthy 2 slightly diseased	Carnation R.F.	5 plants healthy 1 badly diseased 4 slightly diseased	Carnation R. 107	3 plants rotted to about ¼ inch in depth all around 1 cracked almost in two from the infection 6 badly infected Majority cracked and rotted almost thru (Fig. 9)
Carnation R. 121-5	8 plants healthy 2 slightly diseased 1 small lesion below ground about one inch long; 1 lesion on one side about 1/16 inch wide and 4-6 inches long, extending up to first branches	3 plants healthy 2 slightly diseased 5 with pronounced lesions of some depth and several inches in length (*Fig.* 10)	Eggplant I	8 plants healthy 2 slightly diseased	Carrot	10 plants healthy
Cauliflower	10 plants healthy	1 plant healthy 3 slightly diseased 6 with pronounced lesions of some depth on one side of the stem	Lettuce	10 plants healthy	Potato R.P.C.	10 plants healthy
Cotton I	10 plants healthy	5 plants healthy 5 slightly diseased Sclerotia and small round, black lesions present	Thistle	10 plants healthy	Radish	10 plants healthy
Check	10 plants healthy	10 plants healthy	Check	10 plants healthy	Check	10 plants healthy

Flats (9x12 inches) were infected as in Experiment 7, and a varying number of cuttings, seeds, and plants placed in them on March 7, 1914. Pure cultures from the diseased plants in each flat were made, and Rhizoctonia was isolated in each case. Following, the results of the experiment are taken up in detail.

"*Alternanthera R.A.C.*" *on Alternanthera.*—48 cuttings. On March 18 all were dead. The infection was first noticed as a small, brown lesion on one side at the surface of the ground; later the lesion girdled the whole stem. The fungus also attacked the cut surface of the cutting, causing a lesion and in some instances a slow, wet rot. The mycelium, which grew very profusely, attacked the leaves, producing a characteristic rot.

"*Alternanthera R.A.F.*" *on Alternanthera.*—48 cuttings. The experiment was carried out exactly like the above and produced the same results.

"*Alternanthera R.A.F.*" *on Gernanium.*—48 cuttings. These were planted March 20 in the infected flat in which alternanthera cuttings had died. By May 2, 42 of them were rotted while 6 were rooted and healthy.

"*Amaranthus*" *on Amaranthus salicifolius.*—100 seeds. Seeds germinated March 23, and by April 1 all the plants in the flat damped off in a characteristic manner.

"*Aster*" *on Aster.*—100 seeds. Seeds germinated March 18 and a few began immediately to damp off. By April 1, 29 percent had died, while the others remained healthy.

"*Bean*" *on Bean.*—30 seeds. Seeds germinated March 19, and after two months only 5 percent were killed by the fungus.

"*Beet*" *on Beet.*—100 seeds. Seeds germinated March 19 and began to damp off. About 25 percent damped off and later about 25 percent more became scabby because of the formation of small, depressed lesions. Injury here was similar to the infection of beet by the strains from carnation.

"*Carnation*" *on Bean.*—50 plants. On May 8, bean plants about three inches high were transplanted from flats to infected sections (Nos. 157 and 173). The plants took hold readily, and after about two weeks began to show signs of infection. The disease progressed rather slowly; most of the plants produced a few pods before they were killed by the fungus. When pulled up, May 19, every one was diseased or dead (Fig. 8). A detailed description of four typically infected bean plants follows. It will be seen that it corresponds in most details to the descriptions given by Barrus,[9] Fulton,[43] and Hedgcock[60]

> Plant No. 1: Three distinct lesions were present, one directly above the other on the stem. Lesions were oval in shape with a reddish brown band surrounding a lighter colored sunken area. Evidences were present of young lesions over the entire stem and larger roots underground. The wounds extended beneath the cortical layer to the woody tissue.
>
> Plant No. 2: Roots were infected at the joint of their union with the main stem. The lateral root was very badly infected and rotted off entirely. The lesions on the smaller roots were small, depressed, and of a reddish brown color.
>
> Plant No. 3: A large, reddish brown lesion extended from the surface of ground downward 2.5 centimeters. Spots were sunken and extended thru the cortex to woody tissue beneath. Two small sunken areas of a reddish brown color were present on the stem one inch above the surface of the ground.
>
> Plant No. 4: A large, depressed, reddish brown area extended from the surface of the ground downward 2.5 to 3 centimeters, almost encircling the stem. Cortical tissue rotted away exposing the woody tissue beneath.

"*Carnation*" *on Beet.*—30 plants. On May 8, young beet plants were transplanted to a section (No. 158) infected with Rhizoctonia from carnation. By

May 20 they all showed some scab. A number were infected at the crown, where a large number of leaves were completely cut off at the base by the fungus. Several beets had depressed lesions which extended deep into the tissues.

"Carnation" on Cabbage.—25 plants. On May 8, young cabbage plants were transferred from flats to a section (No. 163) in the greenhouse infected with a soil culture of Rhizoctonia from carnation. Some of these plants grew to maturity, but when they were pulled up, May 21, the stems and roots were covered with black, depressed lesions (Fig. 11). Ninety percent of the plants set in the bench were infected in this way. Where the leaves touched the soil the fungus caused a slow, wet rot.

"Carnation" on Carrot.—50 plants. Carrot plants were transferred on May 8 from flats to an infected section (No. 158) in the greenhouse. By May 21 only a few had rotted. The rot started at the crown, where the petioles were attacked, and worked down into the tissues of the root and up into the leaves. The rot from the crown goes into the interior of the root, and thus the root does not show any signs of rot on the outside for some time. Occasionally lesions were found on the sides of the carrots and on the larger roots where they branched from the fleshy part.

"Carnation" on Corn.—10 seedlings. Corn seedlings about 8 inches tall were transplanted on May 8 from flats to an infected section (No. 153) in the greenhouse. The plants grew to maturity. When pulled up, only small lesions were to be found on the roots. These were only slightly depressed and did not retard the growth of the plant.

"Carnation" on Eggplant.—25 plants. On May 8, eggplants were transferred to an infected section in the greenhouse (No. 170). The plants reached maturity with no loss. When they were pulled up, no infection was to be found.

"Carnation" on Lettuce.—60 plants. On March 16, lettuce plants were transferred to an infected section (No. 153). By March 24, 16 percent of the plants were killed. No more loss occurred and the plants were cut on April 21.

"Carnation R. 107" on Cabbage.—100 seeds. Seeds germinated March 19 and began to damp off immediately. By May 21 those which did not damp off were infected in various ways. Some had constrictions just at the surface of the soil; others had definite lesions along the stem and larger roots. Where the plants were crowded, spots of various sizes were formed on the lower leaves which touched the soil.

"Carnation R.M.2" on Carrot.—150 seeds. Seeds germinated March 18. When the experiment was discontinued, May 21, only 10 percent of the carrots were infected at the crown. One showed a constriction which was quite marked.

"Carnation R.F." on Beet.—100 seeds. Seeds germinated March 16 and began to damp off immediately, so that by March 24, 40 percent of the plants were dead. The remainder, when examined on May 21, were all more or less scabby. Some were rotted at the crown.

"Carnation R.F.2" on Bean.—30 seeds. Seeds germinated March 19. When the experiment was discontinued, May 8, but slight infection could be noticed.

"Carrot" on Carrot.—150 seeds. Seeds germinated March 16. By May 21 only a few of the carrots were infected. An occasional plant showed crown rot, which was especially noticeable at the base of the leaves.

"Cauliflower" on Cabbage.—100 seeds. Seeds germinated March 13. A few seedlings began to damp off March 14 and by May 21 most of the plants were infected. Lesions could be found on the stems, occasionally one girdling the whole stem and forming a sort of constriction as the plant developed. A number of spots varying in size could also be found on the lower leaves which touched the soil.

"Chenopodium" on Alfalfa.—100 seeds. Seeds germinated March 13. Two weeks later 60 percent of the seedlings had damped off in a characteristic manner.

"Clover" on Clover.—150 seeds. Seeds germinated March 12 and began to damp off slowly. By March 21, however, the plants had reached sufficient size so that no more damping-off occurred. In all about 10 percent of the seedlings were diseased.

"*Coleus I*" *on Coleus.*—100 seeds. The seeds were all killed by the fungus as they were germinating.

"*Coleus I*" *on Coleus.*—48 cuttings. By March 18 all the cuttings had rotted off. Infection began as small spots at the surface of the ground or at the callus. Underground lesions of all sizes were produced, from small spots to places where the whole stem was girdled. The leaves of the cuttings were overrun with mycelium, the fungus in many cases rotting them off.

"*Coleus II*" *on Chrysanthemum.*—48 cuttings. The old infected flat in which the coleus cuttings had rotted off was planted to chrysanthemum cuttings March 20. By March 27 all of them had rotted off at the surface of the ground. In some a soft, wet rot was produced.

"*Coleus II*" *on Coleus.*—100 seeds. Seeds germinated March 24 and began to damp off slowly. By May 21 only 30 percent of the plants were still healthy.

"*Coleus II*" *on Coleus.*—48 cuttings. All cuttings rotted off as with "Coleus I." The red-colored cuttings rotted off faster and were much more susceptible than those of the green variety.

"*Corn*" *on Corn.*—50 seeds. Seeds germinated March 17. The plants grew to maturity. When pulled up, no signs of infection were noticed.

"*Cotton I*" *on Cotton.*—50 seeds. The fungus caused a rotting of the seeds as they germinated.

"*Cotton III*" *on Cotton.*—50 seeds. Results same as preceding.

"*Dianthus barbatus S.M.*" *on Dianthus barbatus* (*Sweet William*).—100 seeds. Seeds germinated March 19 and began to damp off immediately. By May 22, 50 percent of the seedlings were diseased.

"*Dianthus barbatus N. P.*" *on Dianthus barbatus* (*Sweet William*).—100 seeds. Results same as preceding.

"*Dianthus plumarius*" *on Dianthus plumarius.*—100 seeds. Seeds germinated March 14. By May 22, 80 percent of the plants had damped off.

"*Dianthus sequeri*" *on Dianthus sequeri.*—100 seeds. Seeds germinated March 18 and began to damp off immediately. By May 22 only about 25 percent were still healthy.

"*Eggplant I*" *on Eggplant.*—150 seeds. Seeds germinated March 23. By May 8 only 3 to 4 percent of the plants had damped off.

"*Eggplant II*" *on Eggplant.*—150 seeds. Seeds germinated March 23. The fungus caused a rot of the seeds at germination.

"*Lavatera*" *on Lavatera trimestris.*—100 seeds. Seeds germinated March 12. By May 22 about 25 percent of the seedlings had damped off (Fig. 14). On the remainder, lesions of various sizes were present, which in some cases girdled the stem just below the surface of the soil and formed a collar, or constriction.

"*Lettuce*" *on Lettuce.*—125 seeds. Seeds germinated March 13. By April 1 all the young plants had damped off.

"*Poinsettia*" *on Euphorbia variegata.*—100 seeds. Seeds germinated March 23. By May 22, 6 percent of the plants had damped off.

"*Salvia*" *on Salvia splendens.*—100 seeds. Seeds germinated March 23. By May 8, 6 percent of the seedlings had damped off. By May 21, 4 of the plants were infected. Lesions extending into the woody tissues were present on the stem.

"*Salvia*" *on Salvia splendens.*—48 cuttings. These cuttings rotted off very rapidly. Wherever the leaves touched the soil, they were rotted also. By April 7, 41 cuttings were diseased and 7 were rooted and healthy.

"*Sugar Cane*" *on Amaranthus salicifolius.*—100 seeds. Seeds germinated March 23. On May 21 all the plants were perfectly healthy. No infection was present.

"*Thistle*" *on Clover.*—100 seeds. Seeds germinated March 13. On May 21 all the plants were healthy.

Additional Inoculations.—On April 1 six flats of infected soil used in the inoculation experiments with carnation cuttings were mixed with soil in larger flats and four hills of potatoes were planted in each. The six flats represented the

six strains "Alternanthera R.A.F.," "Carnation R.F.," "Cauliflower," "Lettuce," "Cotton," and "Dianthus barbatus." Only one or two potato sprouts came up from each hill and these were weak and spindling. After the temperature became too high in the greenhouse, the flats were placed outside, so that the plants would develop further and produce tubers. The strains killed some of the young sprouts and dwarfed the others, showing that they were able to attack the potato plant.

Here, as in the preceding experiments, the death rate of the various plants was quite variable. These differences appear to be due to the virulence of the fungus, to the susceptibility of the plant, or to a combination of factors.

Experiment 10: Inoculation of Various Hosts in the Field with Various Strains of Rhizoctonia

All the inoculation experiments reported so far were conducted in the greenhouse. In the summer of 1914 a fourth of an acre of land was divided into three parts, separated by six-foot strips of ground. Section 1 was inoculated on May 20 with twenty cubic feet of infected soil taken from the inoculated benches in the greenhouse. The soil was spread upon the section, worked under, and watered for several days. Section 2 was left as a check. In Section 3 small bits of pure cultures of various strains of Rhizoctonia were added with the seeds and plants. The seeds were planted May 20, and the young plants were put in June 16. Altho the drouth of the summer interfered considerably, the results obtained were sufficient to show that *Rhizoctonia Solani* was active under field conditions as well as in the greenhouse.

No infection occurred in the first two sections. In Section 3 infection was quite marked in a number of cases, especially on cotton, potato, and several greenhouse plants. Where the strain "Cotton I" was added to the cotton seeds, 100-percent infection occurred. In the case of potato, to which "Carnation R.F.2" was added, a marked difference was noticed, the plants in this section being dwarfed and spindling, while in the first two sections they were bushy and strong. The difference in the yield was as marked as the difference in growth of the plants. All the coleus plants infected with "Coleus I" were killed within two weeks after being set out. The same results were obtained from inoculating salvia plants with the strain from salvia.

DISCUSSION OF INOCULATION EXPERIMENTS

In Table 11 are brought together, in tabular form, the results of all the inoculation experiments, with the exception of No. 4, which was carried on primarily to test the comparative virulence of isolated and reisolated strains of Rhizoctonia. The thing that stands out at first glance is the great variation in the mortality of the plants when inoculated with strains from the same host and when inoculated with strains from other sources.

When carnation cuttings were infected, the strains used, with but two exceptions, whether from carnation or from other hosts, were able to cause more or less loss, the mortality of the cuttings ranging in either instance from 0 to 100 percent. Again, the same strains varied in virulence from one year to another, in most cases decreasing in virulence with age. When cuttings other than carnation were used, the results were the same.

When young rooted carnation plants were inoculated, the percentage of loss was much less than with cuttings. Here, however, the carnation strains seemed to be slightly more virulent than those from other sources, altho there was still a great difference in the strains from carnation themselves. Only one of the strains from other sources was unable to attack young rooted carnation plants.

On old carnation plants in the greenhouse which were inoculated by contact, even the carnation strains did not cause a high percentage of infection. However, when plants growing under these same conditions were slightly wounded and then inoculated, the percentage of loss was very high in nearly all the strains studied. When conditions (temperature and moisture) were favorable to the fungus, most of the strains studied were able to infect carnation plants as readily as the carnation strains themselves.

In the majority of cases all strains were able to cause damping-off of various seedlings. There was a great difference in the virulence of strains when inoculated on the same host from which they had been isolated and when inoculated on other hosts. Only occasionally was there any indication of marked specialization, and in no case was such indication corroborated in succeeding experiments.

In older plants, a marked difference in susceptibility was found in the different species. As a rule, the root crops were highly susceptible to attacks of Rhizoctonia. Among these, beet appeared to be the most susceptible. Tomato and eggplant showed a very marked resistance to Rhizoctonia, and this was true to some extent of the potato also, altho under certain conditions it was quite susceptible. This variability of resistance held true for most of the vegetable and field crops other than root crops. Under ordinary conditions, the majority of floricultural plants were not subject to attacks of Rhizoctonia, altho the mycelium of this fungus was known to be present in the soil or even on the plant itself.

From the fact that all the strains studied showed the ability to attack the same species of plant and produce the same characteristic symptoms, it seems clear that they can be included under one form, *R. Solani*. These experiments show further that the virulence of *R. Solani* is very variable, as is also the degree of resistance of the various host plants, both depending on a number of varying factors.

TABLE 11.—SUMMARY OF INOCULATION EXPERIMENTS

Strain	Original date of isolation	Date of inoculation experiment	Host	Condition	Percentage of loss*
Alfalfa.............	1910	1913	Alfalfa	Seedlings	95
		1913	Cabbage	Plants	20
		1913	Carnation	Cuttings	38
		1913	Clover	Seedlings	15
		1913	Corn	,,	0
		1913	Tomato	Plants	0
Alternanthera R.A.C.	1912	1914	Alternanthera	Cuttings	100
		1913	Carnation	,,	92
		1914	,,	,,	96
		1913	,,	Young plants	20
Alternanthera R.A.F.	1912	1914	Alternanthera	Cuttings	100
		1913	Carnation	,,	90
		1914	,,	,,	100
		1913	,,	Young plants	66
		1914	,,	,, ,,	40
		1913	,,	Old plants	0
		1913	,,	,, ,, (wounded)	50
		1914	Geranium	Cuttings	87
Amaranthus	1913	1914	*Amaranthus salicifolius*	Seedlings	100
		1914	Carnation	Cuttings	100
		1914	,,	Young plants	16
Aster	1913	1914	Aster	Seedlings	29
		1914	Carnation	Cuttings	23
Bean		1914	Bean	Seedlings	5
		1913	Carnation	Cuttings	65
		1914	,,	,,	100
Beet...............	1913	1914	Beet	Seedlings	50
		1914	Carnation	Cuttings	100
		1914	,,	Young plants	33
		1913	,,	Old plants	25
Begonia............	1911	1913	,,	Cuttings	100
		1913	,,	Young plants	6
Carnation R.K.	1911	1913	,,	Cuttings	90
		1913	,,	Young plants	85
		1913	,,	Old plants	0
		1913	,,	,, ,, (wounded)	100
Carnation R.O.	1911	1913	,,	Cuttings	0
		1913	,,	Old plants	0
		1913	,,	,, ,, (wounded)	100
Carnation R.H.	1911	1913	,,	Cuttings	80
		1914	,,	,,	100
		1914	,,	Young plants	50
		1913	,,	Old plants	0
		1913	,,	,, ,, (wounded)	100
Carnation R.S.	1911	1913	,,	Cuttings	82
		1913	,,	Young plants	93
		1913	,,	Old ,,	50
		1913	,,	,, ,, (wounded)	100

*In Experiments 1 and 1a the loss from plants wilted is not included in the percentage of loss.

TABLE 11.—*Continued*

Strain	Original date of isolation	Date of inoculation experiment	Host	Condition	Percentage of loss[a]
Carnation R.2	1912	1913	Carnation	Cuttings	100
		1913	"	Young plants	54
		1913	"	Old plants	50
		1913	"	" " (wounded)	100
Carnation R.F.	1912	1913	Beet	Seedlings	98
		1914	"	"	40
		1913	Cabbage	"	40
		1913	Carnation	Cuttings	100
		1914	"	"	94
		1913	"	Young plants	85
		1913	"	" "	100
		1914	"	" "	50
		1913	"	Old plants	0
		1913	"	" " (wounded)	100
		1913	Eggplant	Seedlings	0
		1913	Lettuce	"	60
		1913	"	Plants	50
		1913	Radish	Seedlings	50
Carnation R.M.2	1912	1913	Carnation	Cuttings	96
		1914	"	"	43
		1913	"	Young plants	85
		1913	"	Old plants	0
		1913	"	" " (wounded)	50
		1914	Carrot	Seedlings	10
Carnation R.107	1912	1913	Alfalfa	"	70
		1913	Beet	Plants	100
		1914	Cabbage	Seedlings	75
		1913	Carnation	Cuttings	92
		1914	"	"	91
		1913	"	Young plants	73
		1913	"	Old plants	0
		1913	"	" " (wounded)	100
		1913	"	Old plants	100
		1913	Clover	Seedlings	5
		1913	Corn	"	0
Carnation R.F.2	1913	1914	Bean	"	3
		1914	Carnation	Cuttings	100
		1914	"	Young plants	66
Carnation R.121-5...	1912	1913	Cabbage	Plants	70
		1913	Tomato	"	20
Carnation (Sections 157 and 173)		1914	Bean	"	98
Carnation (Section 158)		1914	Beet	"	95
" (" 163)		1914	Cabbage	"	90
" (" 158)		1914	Carrot	"	10
" (" 153)		1914	Corn	Seedlings	0
" (" 170)		1914	Eggplant	Plants	0
" (" 153)		1914	Lettuce	"	16

[a]See footnote, page 360.

TABLE 11.—*Continued*

Strain	Original date of isolation	Date of inoculation experiment	Host	Condition	Percentage of loss*
Carrot		1913	Beet	Plants	0
		1913	Carnation	Cuttings	66
		1914	,,	,,	30
		1913	,,	Young plants	13
		1913	,,	Old plants	0
		1913	,,	,, ,, (wounded)	0
		1914	Carrot	Seedlings	5
		1913	Radish	,,	98
		1913	Turnip	,,	50
Cauliflower	1912	1913	Cabbage	,,	98
		1914	,,	,,	97
		1913	,,	Plants	90
		1913	Carnation	Cuttings	100
		1914	,,	,,	100
		1913	,,	Young plants	40
		1914	,,	,, ,,	26
		1913	,,	Old plants	75
		1913	Lettuce	Seedlings	3
		1913	Tomato	Plants	0
Chenopodium	1913	1914	Alfalfa	Seedlings	60
		1914	Carnation	Cuttings	31
Clover	1912	1913	Alfalfa	Seedlings	100
		1914	Carnation	Cuttings	75
		1913	Clover	Seedlings	99
		1914	,,	,,	10
		1913	Corn	,,	0
Coleus I	1912	1913	Carnation	Cuttings	100
		1914	,,	,,	100
		1913	,,	Young plants	40
		1914	,,	,, ,,	23
		1914	Coleus	Seedlings	100
		1914	,,	Cuttings	100
Coleus II	1913	1914	Carnation	,,	100
		1914	Chrysanthemum	,,	100
		1914	Coleus	Seedlings	70
		1914	,,	Cuttings	100
Corn	1912	1913	Alfalfa	Seedlings	8
		1914	Carnation	Cuttings	51
		1913	Clover	Seedlings	2
		1913	Corn	,,	0
		1914	,,	,,	0
Cotton I	1911	1913	Cabbage	Plants	50
		1913	Carnation	Cuttings	100
		1914	,,	,,	62
		1913	,,	Young plants	87
		1914	,,	,, ,,	56
		1914	Cotton	Seedlings	100
		1913	Tomato	Plants	0
Cotton II	1912	1913	Carnation	Cuttings	100
		1914	,,	,,	91
		1913	,,	Young plants	46
		1913	,,	Old plants	0
		1913	,,	,, ,, (wounded)	50
		1913	,,	Old plants	100
Cotton III	1912	1914	,,	Cuttings	70

*See footnote, page 360.

TABLE 11.—*Continued*

Strain	Original date of isolation	Date of inoculation experiment	Host	Condition	Percentage of loss*
Cotton III	1912	1913	Carnation	Young plants	28
		1914	Cotton	Seedlings	100
Dianthus barbatus S.M.	1913	1914	Carnation	Cuttings	98
		1913	,,	Old plants	75
		1914	*Dianthus barbatus*	Seedlings	50
Dianthus barbatus N.P.	1913	1914	Carnation	Cuttings	100
		1914	,,	Young plants	60
		1914	*Dianthus barbotus*	Seedlings	50
Dianthus plumarius..	1913	1914	Carnation	Cuttings	100
		1913	,,	Old plants	100
		1914	*Dianthus plumarius*	Seedlings	80
Dianthus sequeri.....	1913	1914	Carnation	Cuttings	100
		1914	*Dianthus sequeri*	Seedlings	75
Eggplant I	1912	1913	Carnation	Cuttings	42
		1914	,,	,,	93
		1913	,,	Young plants	60
		1914	,,	,, ,,	20
		1913	,,	Old plants	0
		1913	,,	,, ,, (wounded)	100
		1913	,,	Old plants	75
		1913	Eggplant	Seedlings	3
		1914	,,	,,	4
		1913	Lettuce	,,	75
		1913	,,	Plants	20
Eggplant II.........	1913	1914	Carnation	Cuttings	83
		1914	Eggplant	Seedlings	100
Lavatera	1913	1914	Carnation	Cuttings	98
		1914	,,	Young plants	36
		1914	*Lavatera trimestris*	Seedlings	95
Lettuce		1913	Carnation	Cuttings	0
		1914	,,	,,	34
		1913	,,	Young plants	13
		1913	,,	Old plants	0
		1913	,,	,, ,, (wounded)	100
		1913	Eggplant	Seedlings	2
		1913	Lettuce	,,	90
		1914	,,	,,	100
		1913	,,	Plants	0
Poinsettia	1912	1913	Carnation	Cuttings	75
		1914	,,	,,	52
		1913	,,	Old plants	0
		1913	,,	,, ,, (wounded)	100
		1914	*Euphorbia variegata*	Seedlings	6
Potato R.P.C.	1912	1913	Beet	,,	50
		1913	,,	Plants	0
		1913	Carnation	Cuttings	90
		1913	,,	Young plants	0

*See footnote, page 360.

TABLE 11.—*Concluded*

Strain	Original date of isolation	Date of inoculation experiment	Host	Condition	Percentage of loss*
Potato R.P.C.	1912	1913	Radish	Seedlings	15
Potato R.P.I.	1912	1913	Carnation	Cuttings	65
		1913	,,	Young plants	50
		1913	,,	Old plants	0
		1913	,,	,, ,, (wounded)	100
Potato R.P.O.		1913	,,	Cuttings	58
		1913	,,	Young plants	43
		1913	,,	Old plants	0
		1913	,,	,, ,, (wounded)	50
Potato R. Sol.		1913	,,	Cuttings	60
		1913	,,	Old plants	0
		1913	,,	,, ,, (wounded)	100
		1913	,,	Old plants	75
Radish		1913	Beet	Plants	0
		1913	Radish	Seedlings	1
		1913	Turnip	,,	99
Salvia	1912	1913	Carnation	Cuttings	2
		1914	,,	,,	47
		1913	,,	Young plants	33
		1914	*Salvia splendens*	Seedlings	10
		1914	,,	Cuttings	85
Sedum	1913	1914	Carnation	,,	100
		1914	,,	Young plants	20
Sugar cane	1912	1914	*Amaranthus salicifolius*	Seedlings	0
		1913	Carnation	Cuttings	90
		1914	,,	,,	24
		1913	,,	Young plants	13
Thistle		1913	,,	Cuttings	33
		1914	,,	,,	47
		1913	,,	Young plants	14
		1913	,,	Old plants	0
		1913	,,	,, ,, (wounded)	100
		1914	Clover	Seedlings	0
		1913	Eggplant	,,	5
		1913	Lettuce	,,	60
		1914	,,	Plants	0

*See footnote, page 360.

GROWTH ON MEDIA

In the course of these studies thirty-eight strains of Rhizoctonia were grown on five of the more common vegetable-extract agars and a solid synthetic medium. The composition of these media may be found in the appendix, together with a complete description of the growth of the various strains on them.

As a rule the fungus isolated from carnation plants, when grown on green-bean agar, produced a rapid-growing mycelium, which was practically all aerial, loose, and tufted. The most characteristic feature was the production of concentric zones, tho this was not invariable. Of the many hundred cultures made during the past three years from diseased carnation plants on green-bean agar, 90 percent have shown this zonation. This characteristic was influenced by neither light nor temperature. A typical growth on this medium is shown in Fig. 20, "Carnation R.H." A few of the carnation strains grown on the same medium and showing the same type of mycelium produced very indistinct zonation or none, as shown in Fig. 20, "Carnation R.F." Zonation persisted to some extent when the carnation strains were grown on other media than green-bean agar, but it was not so characteristic.

The two strains from potato did not grow so rapidly nor quite so luxuriantly on green-bean agar as did the carnation strains, but they produced the same even, tufted, zonate growth. Here the zones were closer together. (See Fig. 20, "Potato R. Sol.")

The growth of the strain from corn on green-bean agar was similar to that of "Potato R. Sol."

The growth on green-bean agar of the strains from eggplant, lettuce, Chenopodium, and thistle was different from any of the other forms in that the mycelium grew along the surface, running out radially in strands, which became larger and more tufted at the edge. (See Fig. 21, "Eggplant I.")

The strains isolated from alternanthera, coleus, salvia, and poinsettia, when grown on green-bean agar, showed the same even, fluffy to tufted growth. This was also characteristic of the strains from cauliflower, cotton, and sugar cane. Zonation in these strains was varied. (See Fig. 21.)

The strain from onion when grown on this agar differed radically from the others. The mycelium was bright colored, finer, and almost all submerged. (See Fig. 20.)

The other strains studied on green-bean agar cannot be put in definite groups, as they shade into one another. However, the growth of the mycelium was somewhat similar in each case; practically the only difference noted was in the extent of the zonation.

On corn-meal agar the growth of the strains was similar to a large extent; the only great difference noted was in rapidity of growth. Zonation was very rare on this medium.

The growth of the strains on oat agar was somewhat variable; zonation was sometimes present and sometimes absent.

The most characteristic feature of the growth of the majority of the strains on potato agar was the turning brown of both the mycelium and the medium. This same characteristic, but to a less degree,

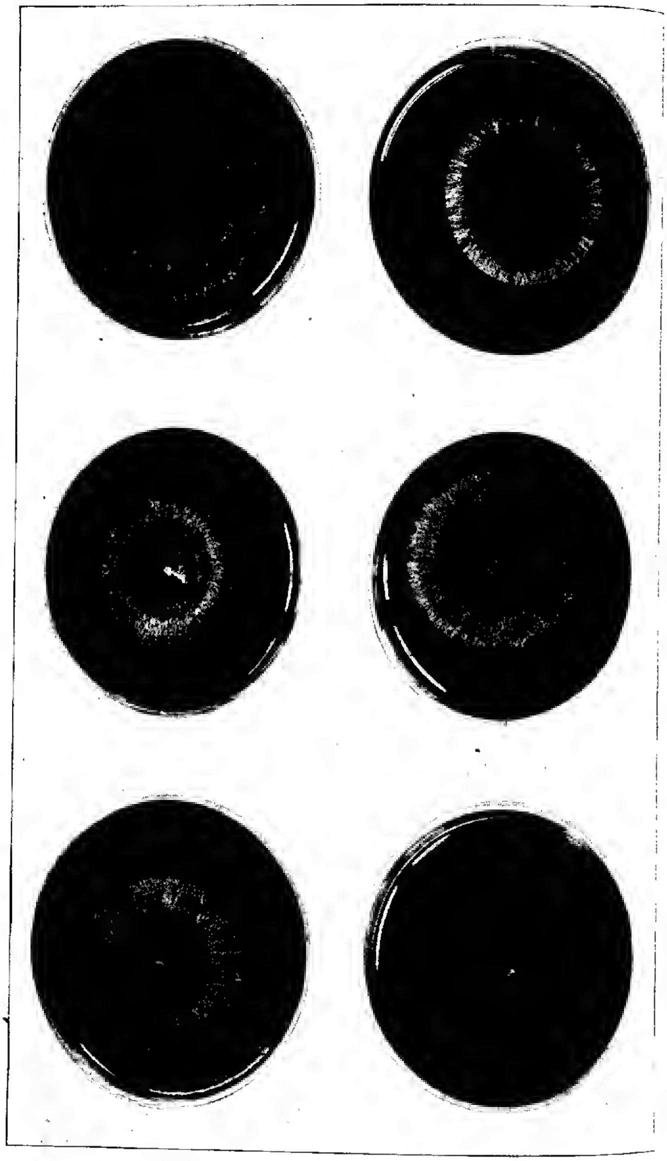

FIG. 20.—CULTURES OF RHIZOCTONIA STRAINS SHOWING DEVELOPMENT OF MYCELIUM ON GREEN-BEAN AGAR (CULTURE 48 HOURS OLD). TOP ROW: (1) CARNATION R.H.; (2) CARNATION R.F. MIDDLE ROW: (1) POTATO R. SOL.; (2) CARROT. BOTTOM ROW: (1) CAULIFLOWER; (2) ONION

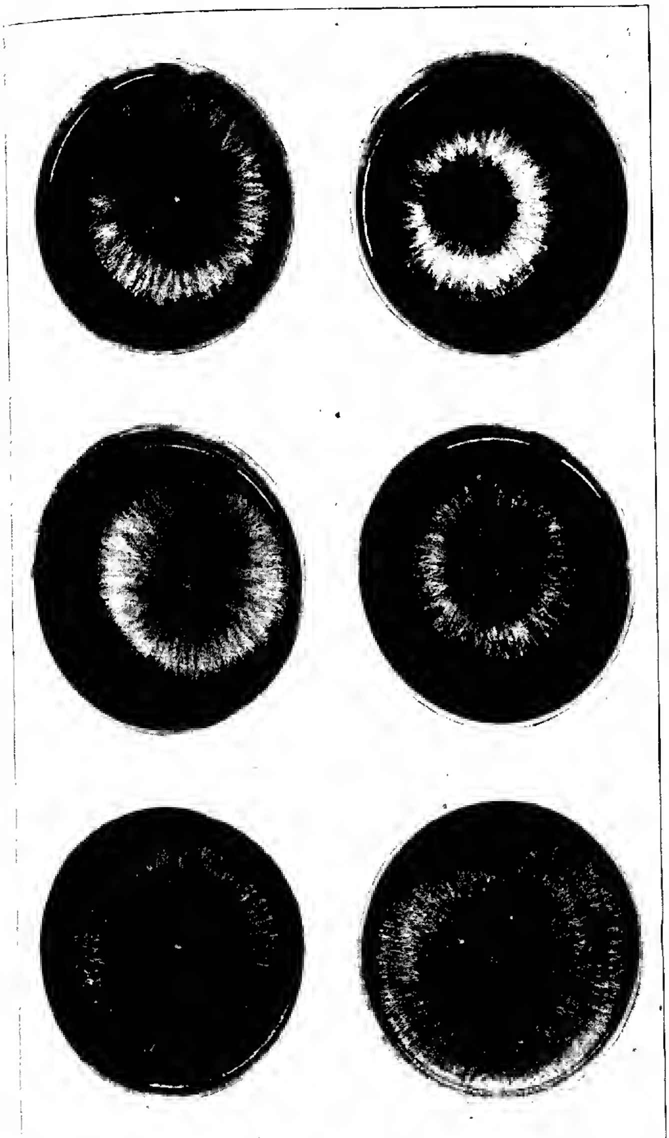

FIG. 21.—CULTURES OF RHIZOCTONIA STRAINS SHOWING DEVELOPMENT OF MYCELIUM ON GREEN-BEAN AGAR (CULTURE 48 HOURS OLD). TOP ROW: (1) ALTERNANTHERA R.A.F.; (2) ALTERNANTHERA R.A.C. MIDDLE ROW: (1) POINSETTIA; (2) COLEUS I. BOTTOM ROW: (1) EGGPLANT I; (2) LETTUCE

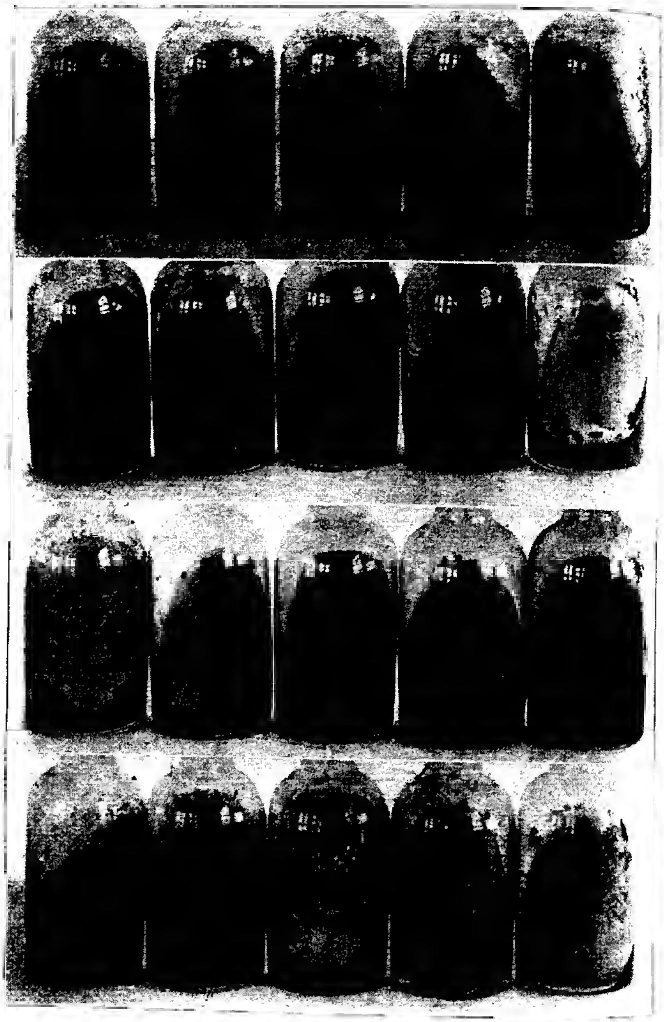

FIG. 22.—CULTURES OF RHIZOCTONIA STRAINS SHOWING DEVELOPMENT OF SCLEROTIA: (1) ALTERNANTHERA R.A.C.; (2) SALVIA; (3) POINSETTIA; (4) ALTERNANTHERA R.A.F.; (5) COLEUS; (6) EGGPLANT II; (7) EGGPLANT I; (8) LETTUCE; (9) CHENOPODIUM; (10) THISTLE; (11) CARNATION R.F.2; (12) CARNATION R.S.; (13) CARNATION R.2; (14) CARNATION R.H.; (15) CARNATION R.O.; (16) ASTER; (17) COTTON I; (18) BEET; (19) CARROT; (20) BEAN

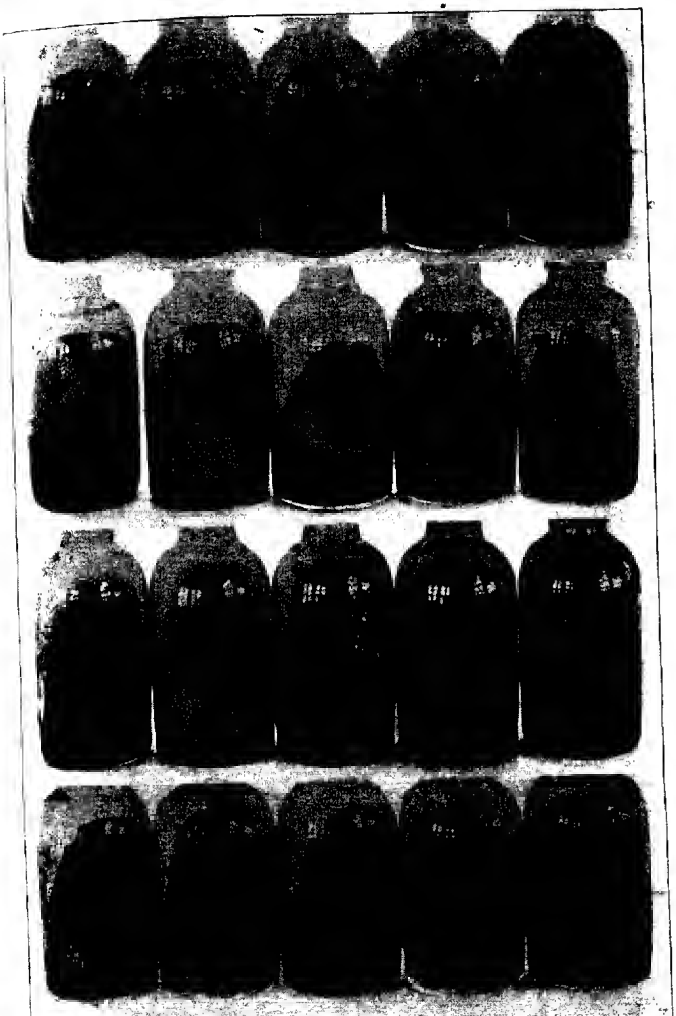

FIG. 23.—CULTURES OF RHIZOCTONIA STRAINS SHOWING DEVELOPMENT OF SCLEROTIA: (1) AMARANTHUS; (2) PANSY; (3) LAVATERA; (4) SWEET ALYSSUM; (5) LOBELIA; (6) ALFALFA; (7) CLOVER; (8) CORN; (9) CAULIFLOWER; (10) SUGAR CANE; (11) BUCKWHEAT; (12) RED CLOVER; (13) SEDUM; (14) GYPSOPHILA; (15) ONION; (16) DIANTHUS BARBATUS S.M.; (17) DIANTHUS PLUMARIUS; (18) DIANTHUS SEQUERI; (19) DIANTHUS BARBATUS N.P.; (20) ASTER (CARNATION STRAIN)

was found with the growth on potato-glucose agar. On both these media zonation was usually lacking or indistinct.

On Agar XII most of the strains grew rather poorly and produced a white, flaky growth, with varying zonation.

Early in the study of the characters of the strains on culture media, it was noticed that as there were characteristic differences in growth, so also were there differences in the production of sclerotia.

The strains "Eggplant I," "Lettuce," "Chenopodium," and "Thistle" on green-bean agar all formed sclerotia in a characteristic manner. The sclerotia were white at first and flat, later turning black, and as the culture became older, curling up and becoming crust-like. All four of the forms mentioned above showed these same characteristics, altho they were originally obtained from widely separated localities. (See Fig. 22.) The strain from onion produced sclerotia which were entirely different from those of other strains in that they were small (.5 to 1 millimeter in diamater), perfectly round, bright colored, and developed submerged in the medium. (See Fig. 23.) The strains "Buckwheat," "Carnation R.O.," "Gypsophila," and "Sedum" rarely produced sclerotia in culture. Repeated observations showed that this loss of power to produce sclerotia was the first sign of the degeneration and loss of virulence of the strain.

All the other strains studied produced sclerotia which were at first white, later becoming brown. Altho the sclerotia from the strain from potato are similar to those from carnation when grown on culture media, on the potato tuber they are entirely different. For the most part the Rhizoctonia sclerotia on potato tubers which the writer has examined are flat and hard, have a black luster, and are in many respects like the sclerotia produced in culture media by the strains from eggplant, lettuce, etc.

The only conclusion that can be drawn from this study of the growth of *Rhizoctonia Solani* on media is that the strains are very variable, those from the same host often producing a different growth, even on the same media, and that the differences in various cultural characters which are shown by strains from different hosts are no greater than differences which may be manifested by two different strains isolated from the same host or by the same strain at different ages.

MEASUREMENT OF MYCELIAL CELLS

It was rather difficult to choose a standard in the measurement of the mycelial cells, because the cells varied in size at different ages and on different media. Finally the following standard was chosen: Hyphæ from the outer edge of a twenty-four hour old culture on green-bean agar were selected at random. The length and width of a cell from which the branch arose nearest the tip of the hypha, and

the distance on the inner side from the parent hypha to the first septum of the branch, were measured. Ten cells of each strain were measured, and the averages of these measurements used for comparison.

As shown in Table 12, the measurements varied considerably, and this was true even with strains from the same host. In the three carnation strains measured, the length of the mycelial cells varied from 70μ to 181.7μ, a difference of 111.7μ. However, the average of ten measurements brings the difference down to some extent. A still more striking difference was noted in the strains from *Dianthus*, where the smallest reading was 50μ and the largest 215μ, a difference of 165μ. Similar differences were also found in comparing the two other measurements.

In all cases, altho the table does not bring out this point, different measurements of the cells of the various strains overlapped. For ex-

TABLE 12.—MEASUREMENTS OF MYCELIAL CELLS OF RHIZOCTONIA

Strain	Length of cell	Width of cell	Distance from cell to septum of branch
	μ	μ	μ
Alfalfa	152.04	5.76	10.08
Alternanthera R.A.C.	113.40	3.92	6.72
″ R.A.F.	124.60	4.94	9.32
Amaranthus	107.80	4.83	7.98
Bean	180.04	6.57	13.08
Beet	77.92	4.34	6.52
Carnation R.H.	116.09	4.59	10.83
″ R.M.2	141.40	5.60	10.49
″ R.F.2	128.15	5.19	10.92
Carrot	116.64	4.42	9.60
Cauliflower	119.64	4.20	9.60
Chenopodium	175.56	5.43	11.20
Clover	88.20	5.32	8.53
Coleus I	117.60	5.04	10.21
Coleus II	133.28	4.97	10.22
Corn	101.64	4.39	9.24
Cotton I	65.24	5.50	10.18
Dianthus barbatus S.M.	113.12	5.58	9.44
″ ″ N.P.	161.00	5.27	10.58
″ sequeri	131.60	6.29	6.44
″ plumarius	166.95	5.65	13.44
Eggplant I	132.34	4.20	11.65
″ II	148.88	5.60	9.57
Gypsophila repens	122.08	3.55	8.03
Lavatera	91.84	5.89	9.18
Lettuce	119.92	4.39	10.54
Poinsettia	126.20	3.44	7.92
Salvia	111.16	5.01	9.93
Sedum	90.80	4.48	7.00
Sugar cane	113.12	4.09	6.57
Sweet pea	130.48	5.04	8.54
Thistle	138.08	4.62	11.48

ample, while the average length of a cell from "Cotton I" was only 65μ, the largest reading was 127.5μ, which was higher than the smallest measurement of a cell of the strain "Chenopodium," whose average reading was 110μ higher than that of "Cotton I." If measurements are made of hyphæ forty-eight hours old, the differences are still more striking, even in the same strain.

Hence, on the measurement of mycelial cells of *Rhizoctonia Solani*, as on the study of the growth on media, no conclusions can be based in regard to distinguishing the strains of this difficult species.

SOIL SURVEY OF RHIZOCTONIA

As shown in Table 1, *Rhizoctonia Solani* has been observed in almost every state in the Union, and causes injury to a large number of plants under various conditions and in widely different types of soils. To determine to how great an extent Rhizoctonia is actually present in the soil, several surveys were made at the University of Illinois in fields containing a variety of plants.

Survey of the Perennial Garden, Horticultural Grounds, April 28 to May 1, 1914.—During the summer and fall of 1913, Rhizoctonia was isolated from a number of perennial plants in the garden. To determine whether the fungus lived on the dead parts of the plants or in the soil or both during the winter season, a survey was made the following spring.

Since it is somewhat difficult to isolate Rhizoctonia directly from the soil by means of soil cultures, the following method was devised to determine its presence in the soil: Small patches of ground were selected over the field about twenty feet apart, so that the results might give a fair idea of the distribution of the fungus. Each space was cleared except for a small living plant, and the soil thoroly watered. Three sheets of moistened filter paper were then placed on the ground over the plant. To prevent evaporation, a small flat with a layer of wet moss attached to the bottom was placed over the paper. The flats had previously been sterilized in formalin (1–100) and the moss sterilized in the autoclave. Thru several small holes in the bottom of the flat, water was added to the moss from day to day to keep it moist. At the end of the fifth day the plant parts were removed to the laboratory.

The presence of the fungus was determined by means of pure cultures and by microscopic observation. Where the identification depended solely on microscopic observations, the material was left in a covered dish for several days until the strands of the fungus became older, when they could be distinguished more readily by their color.

In thirteen cases out of sixteen Rhizoctonia was found present on the dead or living pieces of plants placed in contact with the soil;

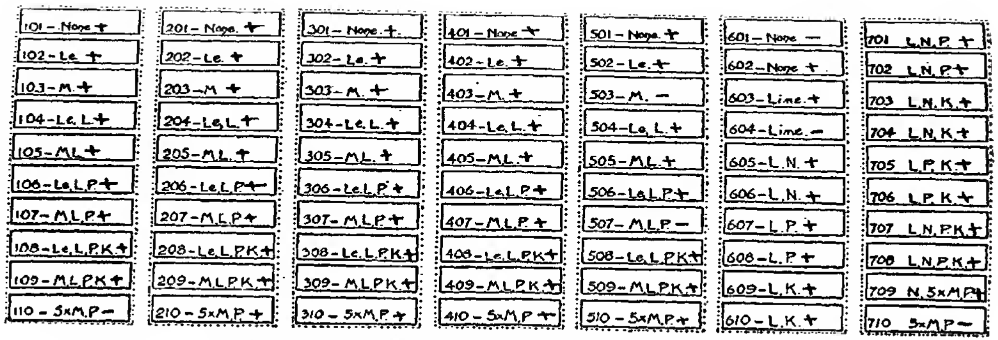

FIG. 24.—DIAGRAM OF AGRONOMY PLOTS ON NORTH FARM[a]

+ indicates Rhizoctonia present; — indicates Rhizoctonia absent; Le= clover plowed under with crop residues; M=farm manure; L=limestone; P=phosphorus (raw phosphate applied to west half and steamed bone meal to east half); K=potassium; N=nitrogen.

The first five series of plots are now in a system of crop rotation of wheat, corn, oats, clover, and alfalfa, with each crop represented every year. Alfalfa is left on one series for five years, while the other crops are rotated on the other four series. Previous to 1911, the 100, 200, and 300 series had been in a three-year rotation of corn, oats, and clover, while the 400 and 500 series had been in a two-year rotation of corn and oats.

The last two series of plots have been kept continuously in corn since 1895, with plant-food elements applied singly and in combination as indicated. The 700 series was discontinued in 1914.

[a]Compiled by the Department of Agronomy, University of Illinois.

hence we may conclude that this fungus was very abundant both in the soil and on the plant parts in contact with the soil.

Survey of Plot Used for Field Inoculation Experiments, May 6 to May 11, 1914.—This plot, formerly used by the Agronomy Department, had been under cultivation for a number of years. The previous season the field had been in potatoes and corn. The old potato stalks were left scattered over the field during the winter.

A survey of the plot was made before plowing, following the same method as was used as in the preceding experiment. Sixteen flats were set out twenty-five feet apart. After five days an examination for the presence of Rhizoctonia was made. By microscopic examination and pure cultures, Rhizoctonia was detected in ten trials out of sixteen on this plot.

Survey of Agronomy Plots on North Farm, September 26 to October 2, 1914.—Here a more extensive survey was conducted. The agronomy plots on the North Farm were chosen for this purpose because of the fact that they had been under continuous cultivation since 1895, and showed the effects of different methods of soil treatment, various systems of crop rotation, and the application of different kinds of food. (For treatments and rotations used, see Fig. 24.) These plots are also typical of the prairie soil, which represents the most extensive and important type of soil in Illinois.

The procedure followed in this survey was modified as follows: Instead of a flat, a seven-inch flower pot, which could be easily sterilized and dried, was employed. Small cheesecloth bags were filled with sphagnum moss; these were sterilized in the autoclave. When ready for use, the bags were moistened and placed in the bottom of the pots and secured in such a way that they remained in position when the pots were inverted. A small patch of soil, one in each plat, was leveled off, only a small living plant or some plant debris being left. Several thicknesses of moistened filter paper were then laid over the spot, and a flower pot was placed over the whole. The pot was pushed into the ground about three inches and the soil heaped up around it on the outside. The pots were left in this condition about one week, during which time the moss was moistened at intervals. Conditions were very favorable to the growth of Rhizoctonia if it was present in the soil. When the pots were lifted, the plant parts or debris with some of the soil were wrapped in the filter paper and placed under bell jars. The contents of the papers were then examined for the presence of Rhizoctonia.

These plots showing the effects of diverse treatments yielded *R. Solani* in sixty-four trials out of seventy. The six negative results were scattered over the field, so that no correlation between the treatment of the plot and the presence of Rhizoctonia can be said to exist.

The results of these experiments admit of no question as to the presence of the fungus *Rhizoctonia Solani* in the soil in the vicinity of Urbana.

PARASITISM OF RHIZOCTONIA SOLANI KÜHN

That *R. Solani* is an active parasite under certain conditions would never be questioned by anyone who had seen a severe attack of carnation stem rot in the field or greenhouse. In the cutting bench this fungus causes damping-off of cuttings in an incredibly short time, while seedlings damp off almost as fast. At times Rhizoctonia causes considerable loss in potato fields. In fact, it may become epidemic and cause serious injury to most of the field, vegetable, and floricultural crops.

The epidemics are apparently due to a combination of factors, such as the presence of a virulent strain of the fungus, a susceptible variety of plant, and optimum conditions of temperature and moisture for infection and development. Under ordinary conditions most of the strains appear to be weak parasites.

The apparently universal presence of Rhizoctonia in the soil, where it can live indefinitely on dead organic matter under ordinary conditions, makes it a dangerous fungus. The fact that it shows no marked specialization and can attack a large variety of weeds assists in harboring the fungus and in keeping up its virulence. The sclerotia and mycelium can live under adverse conditions for several years. Transfers from soil cultures started in December, 1911, kept in the laboratory, and allowed to dry out, yielded pure cultures as late as July, 1914. Soil cultures left in the field during the entire winter yielded the fungus in the spring.

In all but one of the experiments inoculation was brought about without wounding the plants in any way, in many cases the fungus being simply mixed with the soil in which the plants were growing. The results furnish convincing proof of the parasitism of the fungus. The conditions under which all strains manifested their greatest parasitism were primarily a high temperature (above 88° F.) and a soil moisture content either too low or too high for the best development of the plant. When carnation plants growing in soil inoculated with Rhizoctonia were given a heavy watering and the soil was then allowed to dry out, they were killed more rapidly than plants growing under the same conditions but in continually over-watered soil. Plants watered normally died off slowly and the percentage of loss was very much less.

Repeated observations in greenhouse and field have shown that a certain amount of the mycelium must be present before the fungus is able to attack and kill the plant. A small amount of mycelium has always been observed around a carnation plant in the bench a week

or more before the plant showed any signs of being diseased. In fact, a certain amount of mycelium is always present in the carnation soil in the greenhouse, but it is only when the temperature is high that the fungus is able to attack the plants. This explains why stem rot of carnations is more severe during the summer months than in the winter. (See Experiment 6, page 349.) In the field similar conditions are necessary to result in infection of a plant.

Investigations to determine how much vigor the mycelium must attain before the fungus can attack a plant are now in progress, as is also a histological and enzymatic study.

SUMMARY

1. At the present time there are recognized in America two species of truly parasitic Rhizoctonias: The common form, *Rhizoctonia Solani* Kühn (*Corticium vagum* B. & C.), widely distributed and occurring on a great number of hosts; and *R. Crocorum* (Pers.) DC., with a limited distribution on alfalfa and potato tubers. A third Rhizoctonia, *Corticium ochraleucum* (Noack) Burt, is found on the leaves of pomaceous fruit trees, while a fourth species isolated from damped-off onion seedlings is of questionable parasitism.

2. The plants thus far listed as more or less subject to attacks of *Rhizoctonia Solani* Kühn in the United States number about 165 species. All the more important families of dicotyledons are included in this list, as well as a number of monocotyledons, several gymnosperms, and *Equisetum*. Most of the floricultural plants, vegetable and field crops, herbaceous plants, and many weeds are susceptible to attacks of this fungus.

3. The symptoms produced by *Rhizoctonia Solani* Kühn in natural infection are largely similar when appearing on the same type of host. The damping-off of seedlings and cuttings of various plants is identical, as is the rotting of a number of root crops. In most herbaceous plants a stem rot is produced, the symptoms of which are also identical on the various hosts. On very resistant plants lesions only are formed; these are apparently the same on the different hosts.

4. From these inoculation experiments with a large number of different types of plants, we must conclude that all the strains studied, which were obtained from a wide range of hosts of diverse geographical origin, can attack the same species of plant and produce the same characteristic symptoms. No marked specialization was noted in any of the strains. Thus all the strains studied can be included under one form, *Rhizoctonia Solani* Kühn. The inoculation experiments show further that the virulence of *R. Solani* is very variable, as is also the degree of resistance of the various host plants, both depending on a number of varying factors.

5. Studies of the growth of *Rhizoctonia Solani* Kühn on media show that the strains are very variable, those from the same host often producing a different growth even on the same media, and that the differences in various cultural characters which are shown by strains from unlike hosts are no greater than the differences which may be manifested by two different strains isolated from the same host or by the same strain at different ages.

6. Measurements of mycelial cells of *Rhizoctonia Solani* Kühn showed such large variations, not only between strains from different hosts but also between different strains from the same host, that no standard could be determined on for distinguishing the different strains.

7. By means of a local soil survey, it was found that *Rhizoctonia Solani* Kühn is abundant in cultivated land, where it may live either on dead organic matter in the soil or on weeds and other plants.

8. A certain vigor of mycelium must be attained before *Rhizoctonia Solani* Kühn is able to attack a plant. A high temperature (88° F.), together with either too little or too much moisture, determines to a large degree the virulence of the strains. It is only under certain conditions that the fungus becomes a dangerous parasite.

The writer gratefully acknowledges his indebtedness to Dr. F. L. Stevens, Professor of Plant Pathology, and to Dr. J. T. Barrett, former Chief Assistant in Botany, for their kind assistance and encouragement. He wishes also to thank Professor H. B. Dorner, Assistant Chief in Floriculture; Mr. C. C. Rees, formerly Assistant in Floricultural Pathology; and other members of the Division of Floriculture for assistance rendered during the progress of this work.

APPENDIX

COMPOSITION OF MEDIA USED IN EXPERIMENTS

Corn-Meal Agar (*Shear*[a]).—To 4 teaspoonfuls of corn meal add 1 liter of distilled water. Keep in water bath for one hour at a temperature below 60°C. Strain thru gauze, and to the filtrate add 1 percent agar flour. Steam three-quarters of an hour. Filter thru paper tube and place in autoclave for 15 minutes at 115° C.

Green-Bean Agar.—300 grams young string beans cooked in 500 cc water for one hour and strained thru cloth. 15 grams agar (powdered) melted in 500 cc. water. Mix the two, add enough water to make 1000 cc., add 6 to 8 grams egg albumen, and boil in autoclave. Filter thru cotton.

Oat Agar (*Clinton*[b]).—200 grams oats ground fine thru a coffee mill and soaked in 500 cc. water for one hour. 15 grams agar melted in 500 cc. water and strained thru cheesecloth. Mix the two but do not filter, since the most nutrient part of the medium would be lost.

Potato Agar.—300 grams peeled potatoes, sliced as thin as possible and cooked in 500 cc. water for one hour. Strain thru cloth. 15 grams agar (powdered) melted in 500 cc. water. Mix the two and add enough water to make 1000 cc. Add 6 to 8 grams egg albumen (powdered) and boil in autoclave for a short time. Filter thru cotton.

Potato-Glucose Agar.—290 grams peeled potatoes, sliced as thin as possible and cooked in 500 cc. water for one hour. Strain thru cloth and add 20 grams of glucose. 15 grams agar (powdered) melted in 500 cc. water. Mix the two, add enough water to make 1000 cc., add 6 to 8 grams egg albumen (powdered), and boil in autoclave for short time. Filter thru cotton.

Agar (*Cook*[c])

Water	1000.00	cc.
Agar	15.00	grams
Glucose	20.00	”
Ammonium nitrate	1.00	”
Potassium nitrate	1.00	”
Ammonium sulfate	1.00	”
Magnesium sulfate	.25	”
Dipotassium phosphate	.25	”
Calcium chlorid[d]	.01	”

GROWTH ON MEDIA

“ALFALFA”

On Corn-Meal Agar.—Growth poor and rather slow. Mycelium white, fine, submerged, and scarcely visible. No coloring of the medium. No zonation.

On Green-Bean Agar.—Growth poor and slow. Mycelium white, fine, loose, and becoming somewhat tufted. Zonation. Like strain from corn.

On Potato Agar.—Growth rather slow. Characterized by the dark color of the mycelium and the turning of the medium to a darker color. Hyphae loose, fine, and practically all submerged. No zonation.

[a]U. S. Dept. Agr., Bur. Plant Indus., Bul. 252, 15. 1913.
[b]Conn. Sta. Rpt. (1909-10), 32, 760. 1911.
[c]Del. Sta. Bul. 91, 12. 1911.
[d]Omitted from formula used.

Stewart,[125] in reporting the damping-off of alfalfa seedlings in the greenhouse and the crown rot of mature plants in the field, states that "the one causing damping-off of seedlings in the greenhouse is different from the one found in the field. When grown on potato agar (slightly acid, neutral, or slightly alkaline), the former produces a conspicuous dark brown discoloration of the medium, whereas the latter discolors it only slightly. This character may be useful in the identification of the damping-off Rhizoctonia. Such discoloration of the medium is not common among the species of Rhizoctonia." It is interesting to note that the strain obtained from Louisiana causing a damping-off of alfalfa seedlings and a number of other strains showed the same discoloration as the one studied by Stewart.

On Agar XII.—Growth fair. Few loose, erect hyphæ, becoming denser and finally forming an indistinct zone.

"ALTERNANTHERA R. A. C."

On Corn-Meal Agar.—Growth very rapid, but not dense. Mycelium white, loose, aerial, and fine. No zonation.

On Green-Bean Agar.—Growth good. Mycelium tufted and compact, not turning darker. Zonation somewhat distinct at end of third day. Three zones present.

On Oat Agar.—Growth rapid. Mycelium flat, and very compact, forming a mat over the surface. Zonation.

On Potato Agar.—Growth very rapid, with zone formation beginning immediately. Mycelium all aerial and growing very compactly. Plate was covered at end of forty-eight hours and showed two distinct zones and one indistinct.

On Potato-Glucose Agar.—Growth rapid; plate covered in forty-eight hours. Mycelium white, loose, and flaky. Zonation.

On Agar XII.—Growth good. Mycelium white, fine, compact, and somewhat flaky. Zonation.

"ALTERNANTHERA R. A. F."

On the various media this strain produced the same kind of growth in each case as the strain from the cutting bench, except that it grew more rapidly.

"ASTER"

On Green-Bean Agar.—Growth fair. Mycelium white, loose, regular, and flat, becoming somewhat tufted. Four zones formed at end of the fourth day.

On Oat Agar.—Growth fair. Mycelium white, loose, flat, and regular, becoming fluffy and tufted. Like strain "Carnation R. F." Five zones at end of fourth day.

On Potato-Glucose Agar.—Growth slow and poor. Mycelium mostly submerged and turning brown. No zonation.

On Agar XII.—Growth fair. Mycelium white, loose, flat, and regular, becoming somewhat tufted. Zonation.

"BEAN"

On Corn-Meal Agar.—Growth very poor; scarcely visible. Mycelium white, fine, somewhat aerial. No zonation.

On Green-Bean Agar.—Growth slow. Mycelium fine, aerial, loose, and white, darkening with age. Two zones formed, but not very distinct; otherwise like the strain from carrot.

On Potato Agar.—Growth fair. Mycelium fine, more or less submerged, and discoloring the medium only slightly. No zonation.

On Agar XII.—Growth rapid. Mycelium somewhat tufted and dense. Three distinct zones present.

"BEET"

On Green-Bean Agar.—Growth good. Mycelium flat and compact. Several zones present.

"BEGONIA"

On Corn-Meal Agar.—Growth fair. Mycelium rather compact and white. No zonation.

On Green-Bean Agar.—Growth fair. Mycelium white, tufted, and compact. Zonation indistinct.

On Potato Agar.—Growth fair. Mycelium compact, dense, and white; medium turning dark. Zonation.

On Agar XII.—Growth scant. Mycelium white, fine, and loose. No zonation.

"CARNATION R. K."

On Corn-Meal Agar.—Growth good. Mycelium white, making a rather dense growth for corn-meal agar. Zonation indistinct.

On Green-Bean Agar.—Growth good. Like strain "Carnation R. H."

On Oat Agar.—Growth good. Mycelium white, loose, edge tufted. Zonation.

On Potato Agar.—Growth poor. Mycelium loose and scattering, medium turning darker. Zonation indistinct.

On Agar XII.—Growth poor. Mycelium white, loose, and scattered; edge irregular. Zonation indistinct.

"CARNATION R. H."

On Corn-Meal Agar.—Growth fair. Mycelium white, fine, and in loose strands; rather dense at center. No zonation.

On Green-Bean Agar.—Growth good. Mycelium dark at center, loose, and tufted; edge irregular. Zonation very characteristic of the strains isolated from diseased carnation plants.

On Potato Agar.—Growth poor. Mycelium fine and scattered; edge irregular. Mycelium causing a characteristic browning of the medium. Zonation indistinct.

On Agar XII.—Growth poor. Mycelium white, fine, loose, and scattered. No zonation.

"CARNATION R. S."

On Corn-Meal Agar.—Growth fair. Mycelium white, fine, but rather dense at center; edge regular. Zonation.

On Green-Bean Agar.—Growth good. Mycelium loose, white, and tufted; edge regular. Later, mycelium turned brown. Zonation somewhat indistinct.

On Potato Agar.—Growth poor and scant. Mycelium producing a distinct browning of the agar. Zones indistinct.

On Agar XII.—Growth poor. Mycelium white, scant, loose, and flat. Zonation.

"CARNATION R. F."

On Corn-Meal Agar.—Growth good. Mycelium white, loose, and somewhat tufted. No zonation.

On Green-Bean Agar.—Growth fair. Mycelium white, compact, and tufted. Zonation somewhat indistinct.

On Oat Agar.—Growth good. Mycelium white, loose, flat, and fairly dense; edge tufted. Zonation.

On Potato Agar.—Growth poor. Mycelium scant, like that produced by strains from carnation.

On Potato-Glucose Agar.—Growth poor. Mycelium white, loose, scattered, and somewhat flaky; edge very irregular. Zonation.

On Agar XII.—Growth poor. Mycelium white, fine, loose, flat, and scattering; edge very irregular. Zonation indistinct.

"CARNATION R.M.2"

On Corn-Meal Agar.—Growth good. Mycelium white, tufted, and somewhat compact. No zonation.

On Green-Bean Agar.—Growth fair. Mycelium white, tufted, and compact. Zonation indistinct.

On Oat Agar.—Growth fair. Mycelium white, loose, and somewhat flaky at center; edge loose and irregular. Zonation.

On Potato Agar.—Growth poor. Mycelium loose and fine. Zonation indistinct.

On Potato-Glucose Agar.—Growth fair. Mycelium brown, loose, and flat; edge loose and tufted. No zonation.

On Agar XII.—Growth fair. Mycelium white, loose, flat, and scattered. No zonation.

"CARNATION R.D.C."

On Corn-Meal Agar.—Growth good. Mycelium white, loose, tufted, and rather dense. No zonation.

On Green-Bean Agar.—Growth good. Mycelium white, loose, tufted, and dense. Zonation distinct.

On Oat Agar.—Growth fair. Mycelium white, somewhat dense at center, and more tufted at edge. Zonation.

On Potato Agar.—Growth poor. Mycelium loose and flat, darkening slowly ith age. Zonation indistinct.

On Potato-Glucose Agar.—Growth fair. Mycelium white, flat, and flaky at nter; edge loose and fluffy. Zones numerous and distinct.

On Agar XII.—Growth poor. Mycelium white, somewhat flaky at center; edge regular and scattered. Zonation.

"CARROT"

On Corn-Meal Agar.—Growth good. Mycelium white, fine, and somewhat comter. No zonation.

On Green-Bean Agar.—Growth poor. Mycelium loose, flat, and somewhat iffy; white at first, followed by purplish tinge. Zonation not very distinct.

On Oat Agar.—Growth fair. Mycelium white, fine, loose, and flat. Zonation distinct.

On Potato Agar.—Growth fair. Mycelium dark, dense, and compact. Zonaon indistinct.

On Potato-Glucose Agar.—Growth fair. Mycelium dark, loose, flat, and flaky. our to six zones present.

On Agar XII.—Growth slow. Mycelium white, loose, and somewhat flaky. mation.

"CAULIFLOWER"

On Corn-Meal Agar.—Growth poor. Mycelium white, loose, and scant. No zonation.

On Green-Bean Agar.—Growth good. Mycelium white, tufted, and compact; edge regular. Zonation.

On Oat Agar.—Growth good. Mycelium white, fine, loose, flat, and dense, running out in characteristic strands. No zonation.

On Potato-Glucose Agar.—Growth fair. Mycelium dark, loose, flat, and flaky. One zone at outer edge.

On Agar XII.—Growth good. Mycelium white, loose, flat, and flaky. Zonation.

"CHENOPODIUM"

On Green-Bean Agar.—Growth good. Mycelium white, flat, radial, and compact. No zonation.

"CLOVER (RED)"

On Green-Bean Agar.—Growth good. Mycelium flat and compact. Zonation.

"COLEUS I"

On Corn-Meal Agar.—Growth good. Mycelium white, loose, and somewhat compact. No zonation.

On Green-Bean Agar.—Growth good. Mycelium white, tufted, and compact. Zonation indistinct.

On Oat Agar.—Growth good. Mycelium white, loose, and flat; edge fluffy. No zonation.

On Potato Agar.—Growth fair. Mycelium loose and tufted, turning darker with age. No zonation.

On Potato-Glucose Agar.—Growth fair. Mycelium dark, loose, and flaky; edge irregular. Zonation.

On Agar XII.—Growth good. Mycelium loose, dense, and white. No zonation.

"CORN"

On Corn-Meal Agar.—Growth poor. Mycelium white, fine, and scattered. No zonation.

On Green-Bean Agar.—Growth fair. Mycelium loose at edge and somewhat compact, turning darker with purplish tinge. Two distinct zones.

On Potato Agar.—Growth fair. Mycelium dense and compact. Mycelium and medium turned dark. Zonation indistinct.

On Agar XII.—Growth fair. Mycelium white, loose, tufted, and rather dense at center. Zonation.

"COTTON I"

On Green-Bean Agar.—Growth fair. Mycelium loose, tufted, dense, and white. Two zones present.

On Oat Agar.—Growth good. Mycelium white, loose, flat, dense, and radial, later taking on a wrinkled appearance. No zonation.

On Potato-Glucose Agar.—Growth fair. Mycelium white, flat, dense, flaky, and regular; loose at edge. Zonation indistinct.

On Agar XII.—Growth fair. Mycelium flat, somewhat dense, flaky, and white at center; edge loose. Two distinct zones.

"COTTON II"

On Green-Bean Agar.—Growth fair. Mycelium loose, tufted, and fairly dense, later turning brown. Two zones present.

On Oat Agar.—Growth fair. Mycelium white, fine, loose, and flat, forming a mat over surface of the medium. One zone present.

On Potato-Glucose Agar.—Growth fair. Mycelium loose, flat, and fairly dense; edge irregular. Later both mycelium and medium turned brown. Two zones present.

On Agar XII.—Growth fair. Mycelium white, loose, and somewhat tufted. Three zones present.

"DIANTHUS BARBATUS N.P."

On Green-Bean Agar.—Growth fair. Mycelium tufted and compact. Zonation indistinct.

"DIANTHUS BARBATUS S.M."

On Green-Bean Agar.—Growth good. Mycelium tufted and compact. Zonation rather indistinct.

"DIANTHUS PLUMARIUS"

On Green-Bean Agar.—Growth good. Mycelium loose, white, and somewhat tufted; edge regular. Zonation characteristic of the carnation strains.

"DIANTHUS SEQUERI"

On Green-Bean Agar.—Growth good. Mycelium loose, white, and somewhat fluffy; edge regular. Zonation characteristic of carnation strains in all respects.

"EGGPLANT I"

On Corn-Meal Agar.—Growth poor. Mycelium white, fine, and mostly submerged. No zonation.

On Green-Bean Agar.—Growth good. Mycelium white, flat, radial, compact, and dense. One zone at center.

On Oat Agar.—Growth fair. Mycelium white, loose, flat, interwoven, and somewhat tufted. Zonation.

On Potato Agar.—Growth good. Mycelium dark, compact, dense, and radial. No zonation.

On Potato-Glucose Agar.—Growth fair. Mycelium in radial strands, flat, and white. No zonation.

On Agar XII.—Growth fair. Mycelium white, flat, dense, and compact. One zone present.

"GYPSOPHILA"

On Green-Bean Agar.—Growth fair. Mycelium white, fluffy, and somewhat compact. Zonation very characteristic of strains from carnation.

"LAVATERA"

On Green-Bean Agar.—Growth good. Mycelium white, loose, and tufted; edge even. Several zones present.

"LETTUCE"

On Corn-Meal Agar.—Growth fair. Mycelium white, fine, slightly aerial, and somewhat flaky. No zonation.

On Green-Bean Agar.—Growth good. Mycelium white, loose, flat, and rather dense, running out in strands. One indistinct zone present.

On Oat Agar.—Growth fair. Mycelium white, loose, flat, interwoven, and somewhat tufted. One zone present.

On Potato Agar.—Growth fair. Mycelium dark, fine, and practically all submerged. No zonation.

On Potato-Glucose Agar.—Growth good. Mycelium white and flat, running out in radial strands. No zonation.

On Agar XII.—Growth good. Mycelium white, loose, flat, and rather dense. No zonation.

"ONION"

On Green-Bean Agar.—Growth fair. Bright colored mycelium, fine and submerged at center; a little aerial mycelium at the outer edge, where it was somewhat loose. No zonation.

On Potato Agar.—Growth fair. Mycelium fine, scarcely visible, and of a bright color. No zonation.

On Agar XII.—Growth fair. No aerial mycelium. No zonation.

"POINSETTIA"

On Corn-Meal Agar.—Growth fair. Mycelium white, dense, fluffy, and compact. Zonation indistinct.

On Green-Bean Agar.—Growth fair. Mycelium white, loose, compact, and fluffy. No zonation.

On Oat Agar.—Growth good. Mycelium white, loose, flat, and radial; edge somewhat fluffy. No zonation.

On Potato Agar.—Growth fair. Mycelium somewhat flaky and compact. Three zones present.

On Potato-Glucose Agar.—Growth fair. Mycelium brown and flat at center; outer edge white, loose, and somewhat flaky. Zonation indistinct.

On Agar XII.—Growth fair. Mycelium white, flat, dense, and radial, like alternanthera. One zone.

"POTATO R. SOL."

On Corn-Meal Agar.—Growth fair. Mycelium fine and flat. No zonation.

On Green-Bean Agar.—Growth fair. Mycelium loose at edge, compact and fluffy at center. Several zones present, two distinct.

On Potato Agar.—Growth fair. Mycelium white and fluffy. One zone at center.

On Agar XII.—Growth poor. Mycelium mostly submerged and somewhat compact; flaky at center. Zonation.

"POTATO R.P.O."

On Corn-Meal Agar.—Growth fair. Mycelium white, fine, and rather scant. No zonation.

On Green-Bean Agar.—Growth good. Mycelium loose at edge, flat, dense, somewhat fluffy, and rather dark. Three zones present. Growth very much like strains from carnation.

On Potato Agar.—Growth fair. Mycelium dark, loose, and fluffy. Zonation distinct.

On Potato-Glucose Agar.—Growth fair. Mycelium white, flat, loose at edge, and flaky at center. Three zones present.

On Agar XII.—Growth very slow. Mycelium white, dense, and bushy, forming a tuft at the center. No zonation.

"SALVIA"

On Green-Bean Agar.—Growth good. Mycelium white, tufted, and compact. Zonation indistinct.

On Oat Agar.—Growth good. Mycelium white, loose, flat, rather dense, and radial. Zonation indistinct.

On Potato-Glucose Agar.—Growth fair. Mycelium white and flaky at center; edge loose and tufted. Zonation indistinct.

On Agar XII.—Growth good. Mycelium white and flaky at center; edge loose and tufted. Zonation indistinct.

"SEDUM"

On Green-Bean Agar.—Growth good. Mycelium flat and compact. One zone present.

"SUGAR CANE"

On Corn-Meal Agar.—Growth fair. Mycelium white, fine, and scarcely visible. No zonation.

On Green-Bean Agar.—Growth fair. Mycelium white, loose, and tufted. Zones present.

On Potato Agar.—Growth fair. Mycelium white, fine, and practically all submerged. Two indistinct zones present.

On Agar XII.—Growth fair. Mycelium white, fine, and running out in strands from the center. No zonation.

"SWEET PEA"

On Green-Bean Agar.—Growth good. Mycelium flat and compact. One zone present. In many respects like strain from carnation.

"THISTLE"

On Corn-Meal Agar.—Growth fair. Mycelium white, running out in strands; flat at center, and somewhat loose at edge. No zonation.

On Green-Bean Agar.—Growth good. Mycelium white, flat, radial, and compact at center; edge somewhat loose and fluffy. Zonation indistinct.

On Oat Agar.—Growth good. Mycelium white, flat, dense, and radial. No zonation.

On Potato Agar.—Growth fair. Mycelium white, flat, and somewhat compact, running out in strands. No zonation.

On Potato-Glucose Agar.—Growth fair. Characterized by a white, radial, flat mycelium. No zonation.

On Agar XII.—Growth fair. Mycelium white, flat, compact, and flaky at center, becoming looser at edge. No zonation.

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